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AUTHOR Pierson, John E., III
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INSTITUTION Rutgers, The State Univ., New Brunswick, N.J. Curriculum Lab.
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ABSTRACT

The text was prepared to help deaf students develop the skills needed by an employed welder. It uses simplified language and illustrations to present concepts which should be reinforced by practical experience with welding skills. Each of the 12 lessons contains: (1) an information section with many illustrations which presents a concept or procedure in step-wise detail, (2) an outlined review of the material presented, and (3) a list of objective questions to check comprehension of the lesson. The lessons cover the following topics: preparing to be a safe welder, using electricity in welding, identifying TIG welding equipment, selecting tungsten electrodes, using inert gas, action of the arc, using the torch in the flat position, establishing the arc, making a butt weld, making a fillet weld, welding aluminum, and welding stainless steel. (MS)

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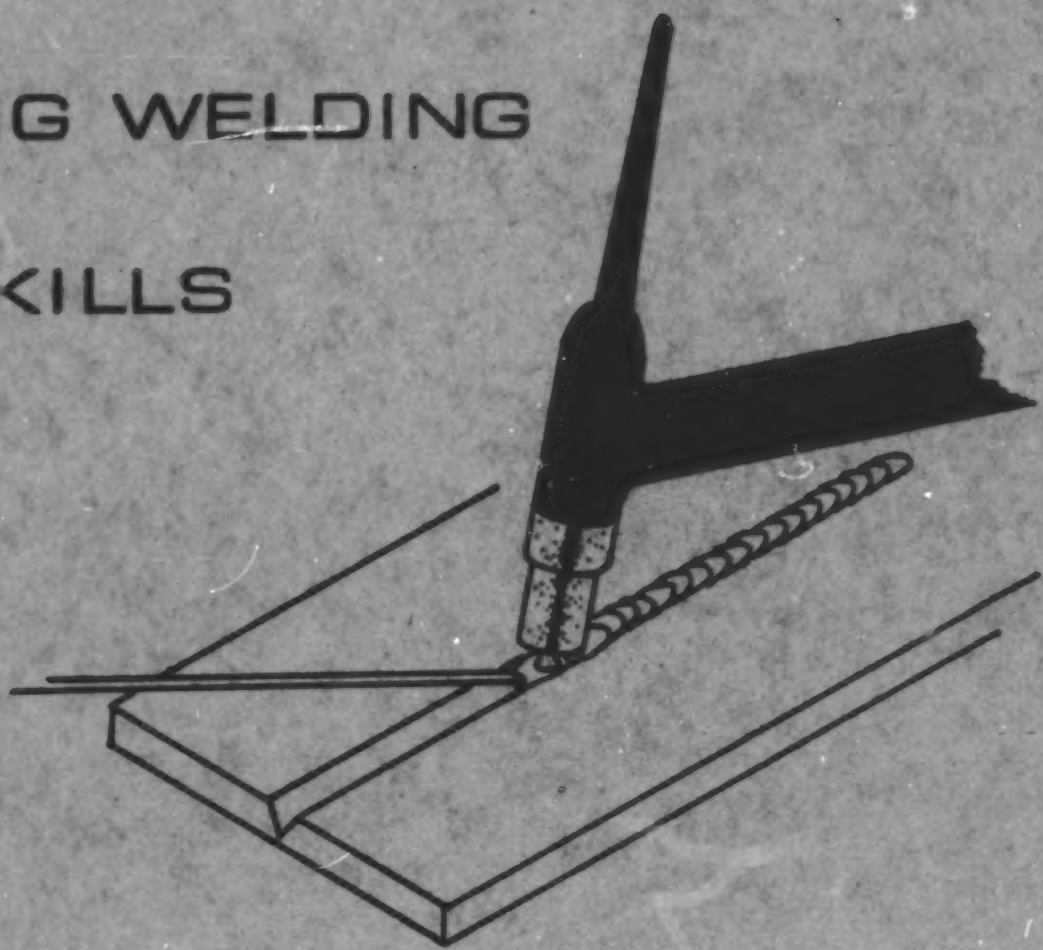
ELEMENTARY TIG WELDING SKILLS



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John E. Pierson III
Marie H. Katzenbach School for the Deaf
West Trenton, New Jersey

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ELEMENTARY TIG WELDING SKILLS

John E. Pierson III

Dr. Charles M. Jochem, Superintendent
Marie H. Katzenbach School for the Deaf
West Trenton, New Jersey

Vocational-Technical
Curriculum Laboratory
Rutgers - The State University
Building 4103 - Kilmer Campus
New Brunswick, New Jersey

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DIVISION OF VOCATIONAL EDUCATION
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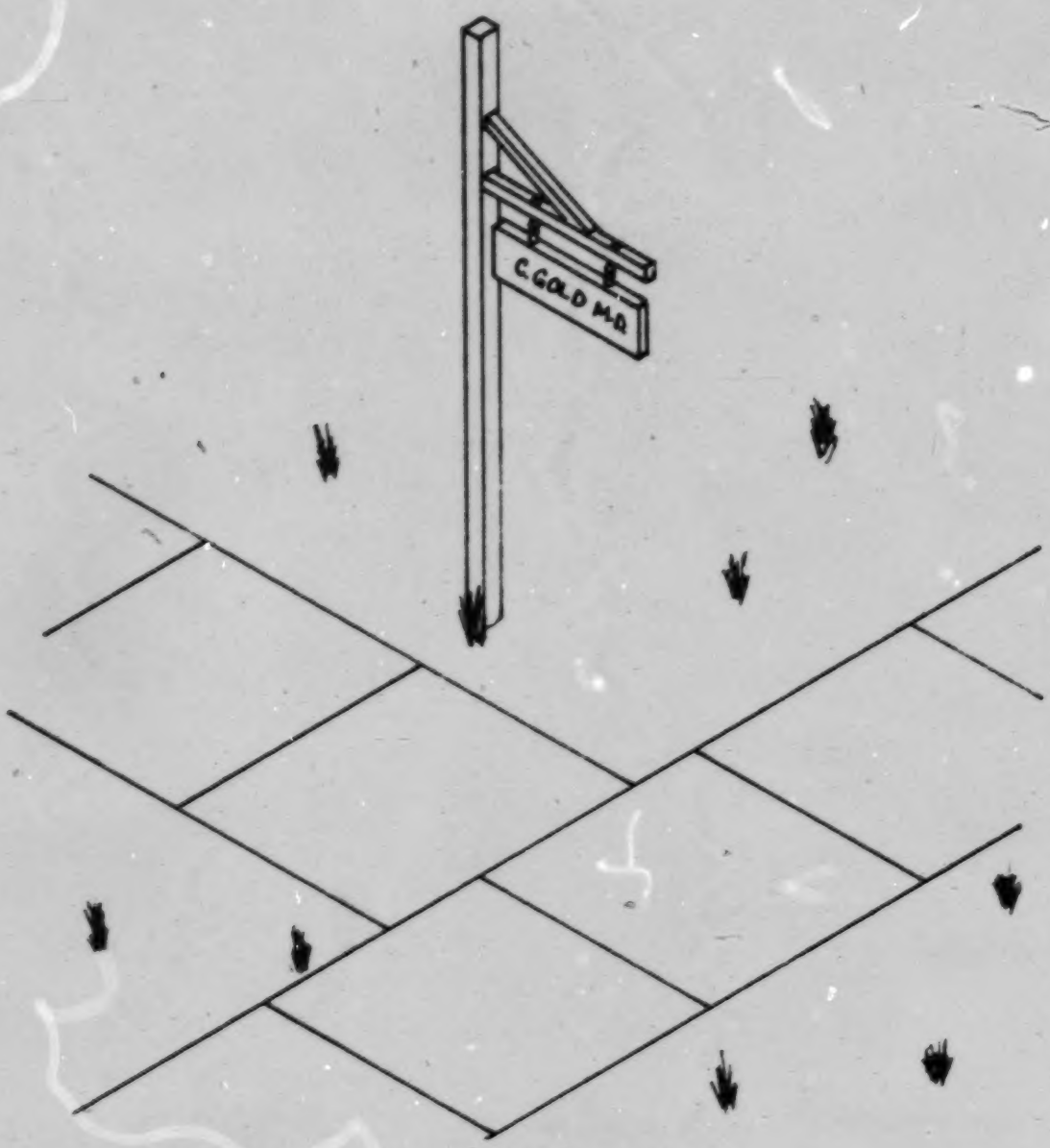
INTRODUCTION

This text was prepared for welding students at the Marie H. Katzenbach School for the Deaf. The language barrier prevents deaf students from achieving at a faster educational rate. This text was designed to help overcome some of the learning handicaps.

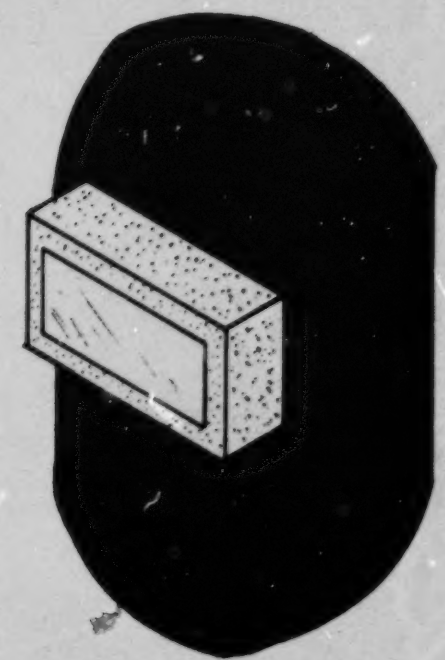
The language and concepts in this text have been simplified. Most of the language form consists of simple, declarative sentences. Illustrations are used throughout the text to supplement and reinforce each verbal concept. Each lesson will be followed by practical experience with each of the welding skills. It should be possible for each student to develop the skills needed by an employed welder.

Safety keeps the doctor away.



Protect yourself. Follow the shop rules.

Wear your welding helmet. The lens keeps dirt and flying pieces of metal out of your eyes.



Helmet

A shade filter lens prevents flash burn to the eyes. Check the number of the shade filter lens in your helmet. It should be No. 10 or larger. The number is on one corner of the lens.

Wear safety glasses. Keep flying pieces of metal out of your eyes. Glasses also protect your eyes from sparks and dirt.

Safety Glasses

Protect your eyes with safety glasses.

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Prevent burns. Protect your hands with gloves.

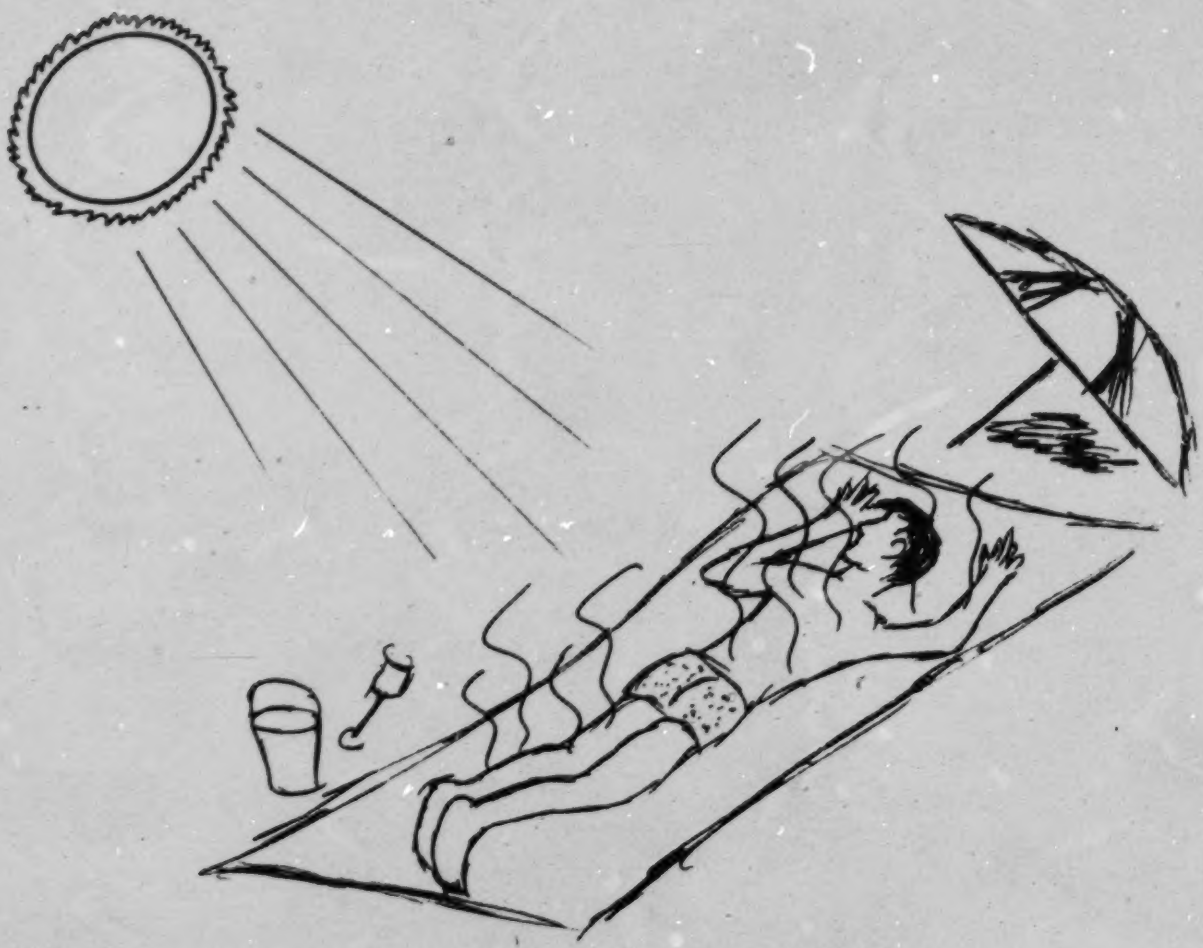
Gloves

Arc welding produces light that can cause sunburn. Protect all parts of your body. Wear a long sleeve shirt and long pants.

Proper dress

Safety shoes with steel toes prevent injuries. Many employers require welders to wear safety shoes.

The sun can burn your skin. The light from the welding arc can also burn.



Sunburn is painful

Protect yourself from burns. Wear a helmet and gloves. Wear shirts with long sleeves and long pants without cuffs.

REVIEW

Accidents can be prevented. Think before you act.

1. Wear safety glasses. They protect your eyes.

2. Wear gloves when you handle hot metal. They prevent burns.

3. Keep your work area clean. Clean work areas prevent tripping accidents.

4. Wear a helmet. The shaded lens protects your eyes and face from flash burn.

5. Remember, metal becomes hot while it is being welded. Develop good working habits.

QUESTIONS

1. Prevent flash burn by wearing _____.

   a. gloves
   b. goggles
   c. helmets

2. Protect the eyes from flying pieces of metal by wearing _____.

   a. goggles
   b. safety glasses
   c. sun glasses

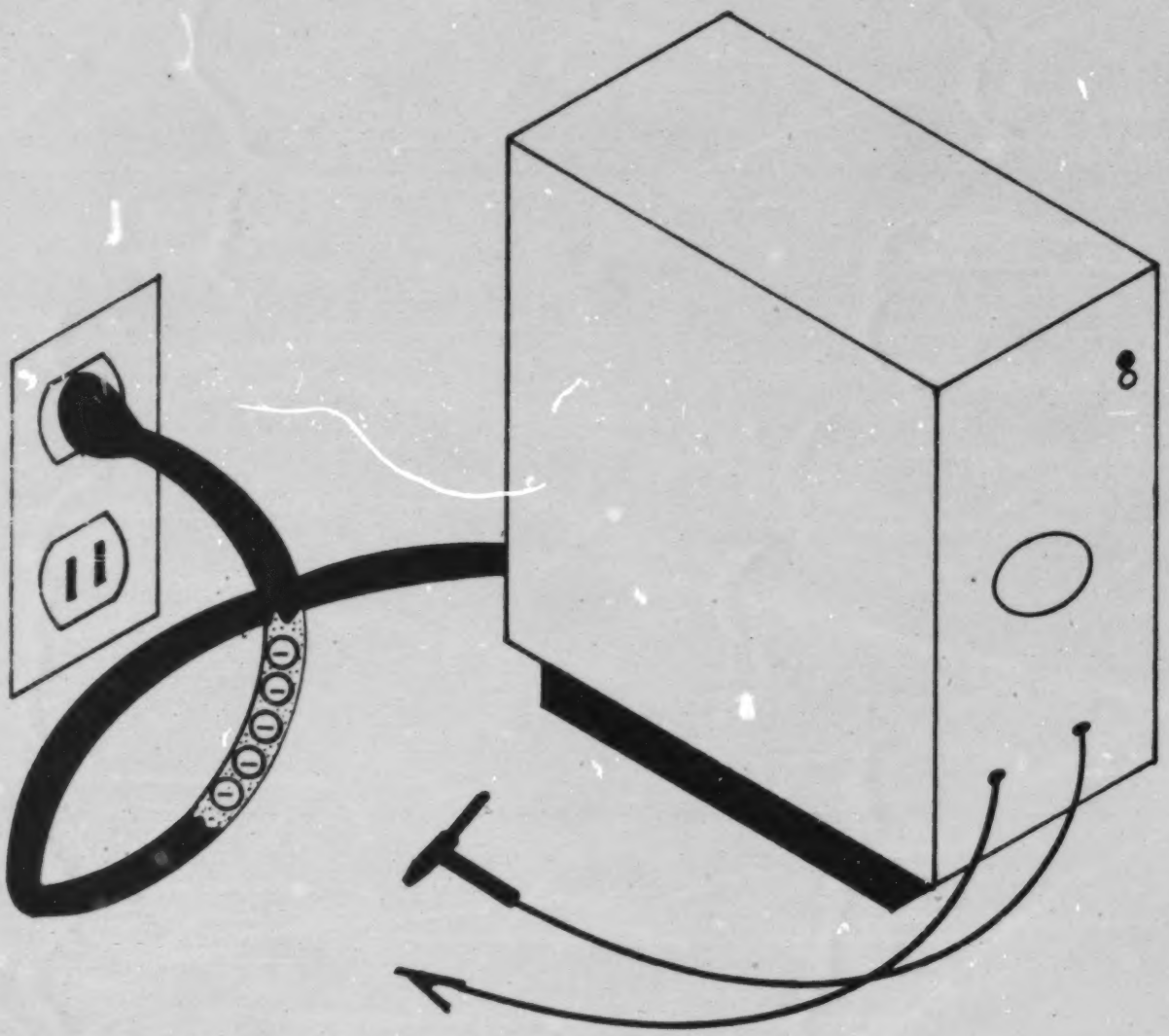
3. Safe clothes for the welder should include _____.

   a. helmets and safety glasses
   b. shoes and goggles
   c. long-sleeve shirts and long pants without cuffs.

4. Protect the hands with _____.

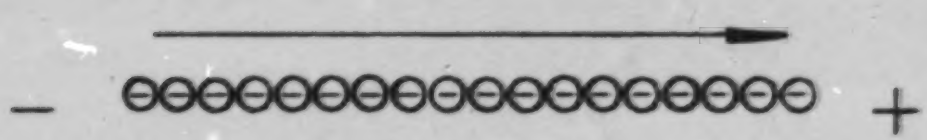
   a. a shield
   b. gloves
   c. a long-sleeve shirt

Arc welding uses electricity. Electricity is a flow of electrons. Electrons are negatively-charged particles.



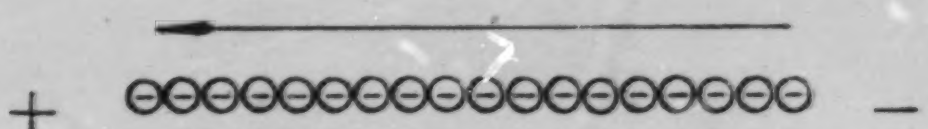
This is the power supply of the welder. The power supply regulates the amount of current needed for welding.

An electron has a negative charge. When electrons are in motion, they move from the negative towards the positive. Electrons are so small that we can't see them.



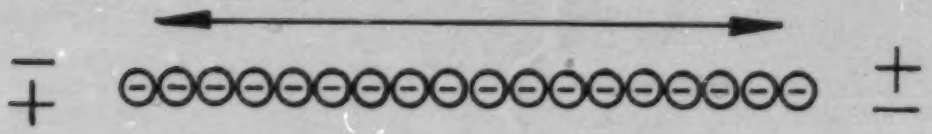
Direction of electron flow

The two kinds of electricity are direct current (D.C.) and alternating current (A.C.). The electrons flow only in one direction with direct current. Automobile batteries are one source of direct current.



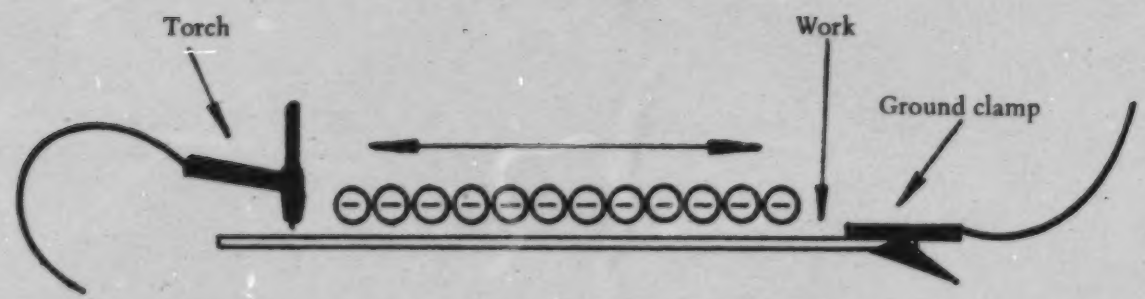
Direct current - one direction

The electron flow keeps changing directions with alternating current (A.C.). The electrons flow toward the positive side, but the positive and negative sides keep changing. The electron flow changes as each side switches from positive to negative. House current, the electricity wired to houses, is an example of alternating current.



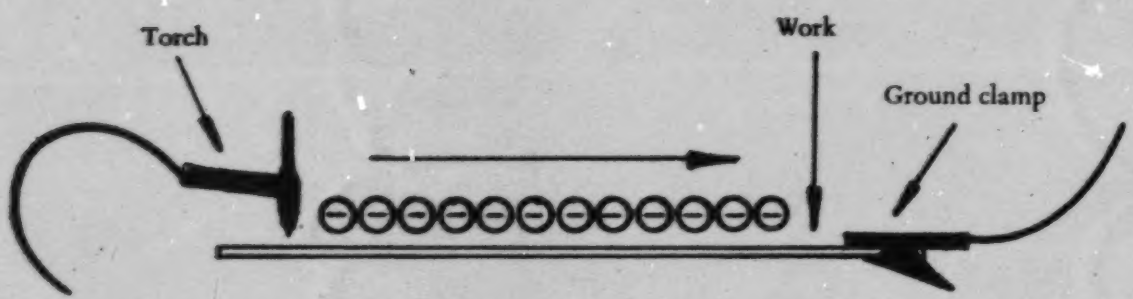
Alternating current - both directions

Alternating current (A.C.) is used in TIG welding. The electrons flow to and from the torch.



A.C. power - electron flow

Direct current straight polarity (D.C.S.P.) is also used for TIG welding. The electron flow is only from the torch. The ground clamp is the positive side.



D.C.S.P. electron flow

Direct current straight polarity (D.C.S.P.) is used to weld stainless steel.

REVIEW

Electricity is a flow of electrons. The electrons can flow in either direction. The flow of electrons changes direction in alternating current (A.C.). They flow in one direction; then they flow in the other direction. The electrons only flow in one direction with direct current.

The kind of electricity used for TIG welding depends on the kind of metal. Aluminum and its alloys are welded with A.C. power. Stainless steel and its alloys are welded with D.C.S.P.

The amount of electricity needed for welding depends on the thickness and kind of metal.

QUESTIONS

1. What is the charge of an electron?
   a. positive
   b. negative
   c. neutral

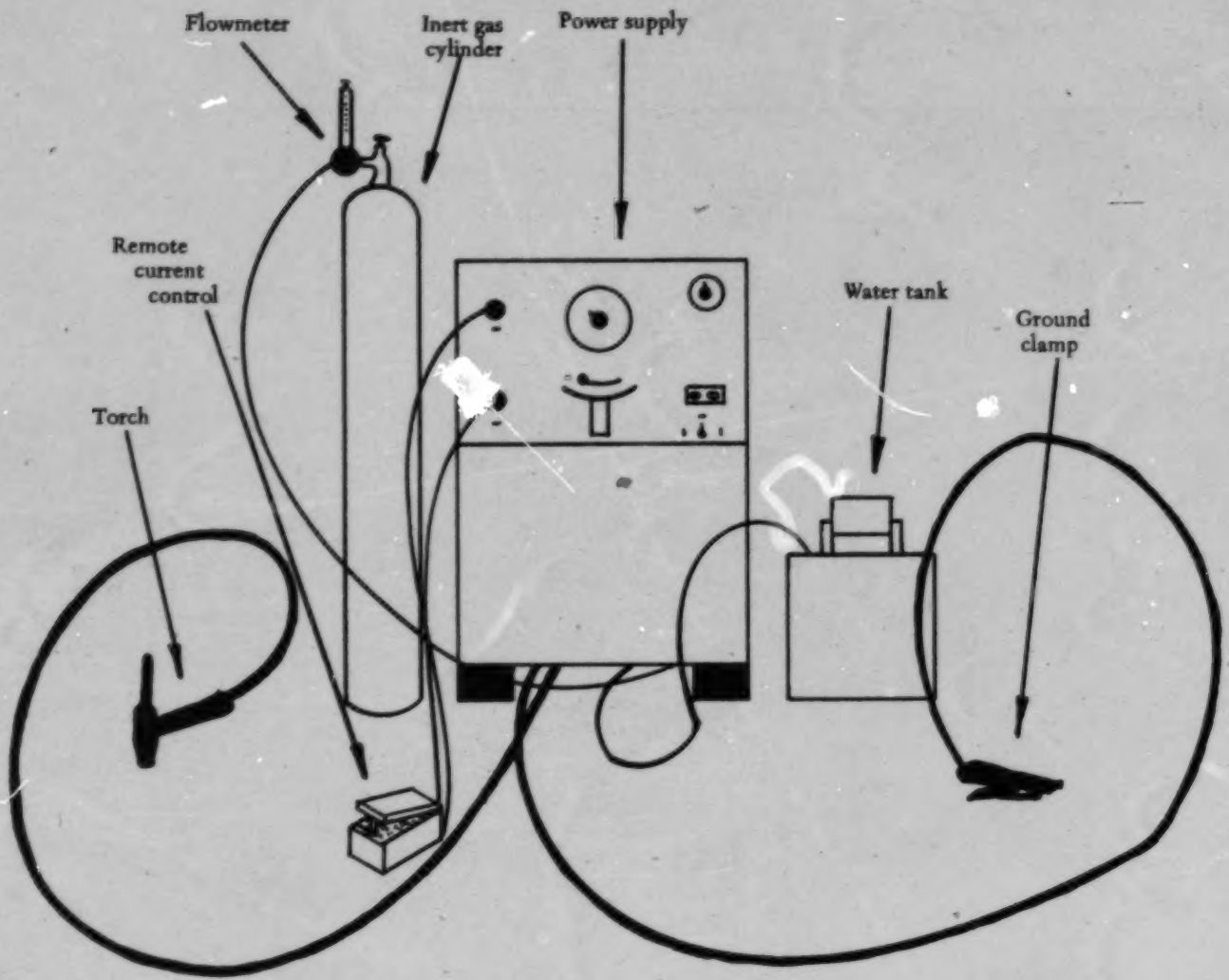
2. When electrons are flowing, which direction do they flow?
   a. towards the positive
   b. towards the negative
   c. in both directions

3. With A.C. power, how many directions do the electrons flow?
   a. one
   b. two
   c. three

4. When using D.C.S.P. to weld, the electrons flow _____ the torch.
   a. from
   b. towards

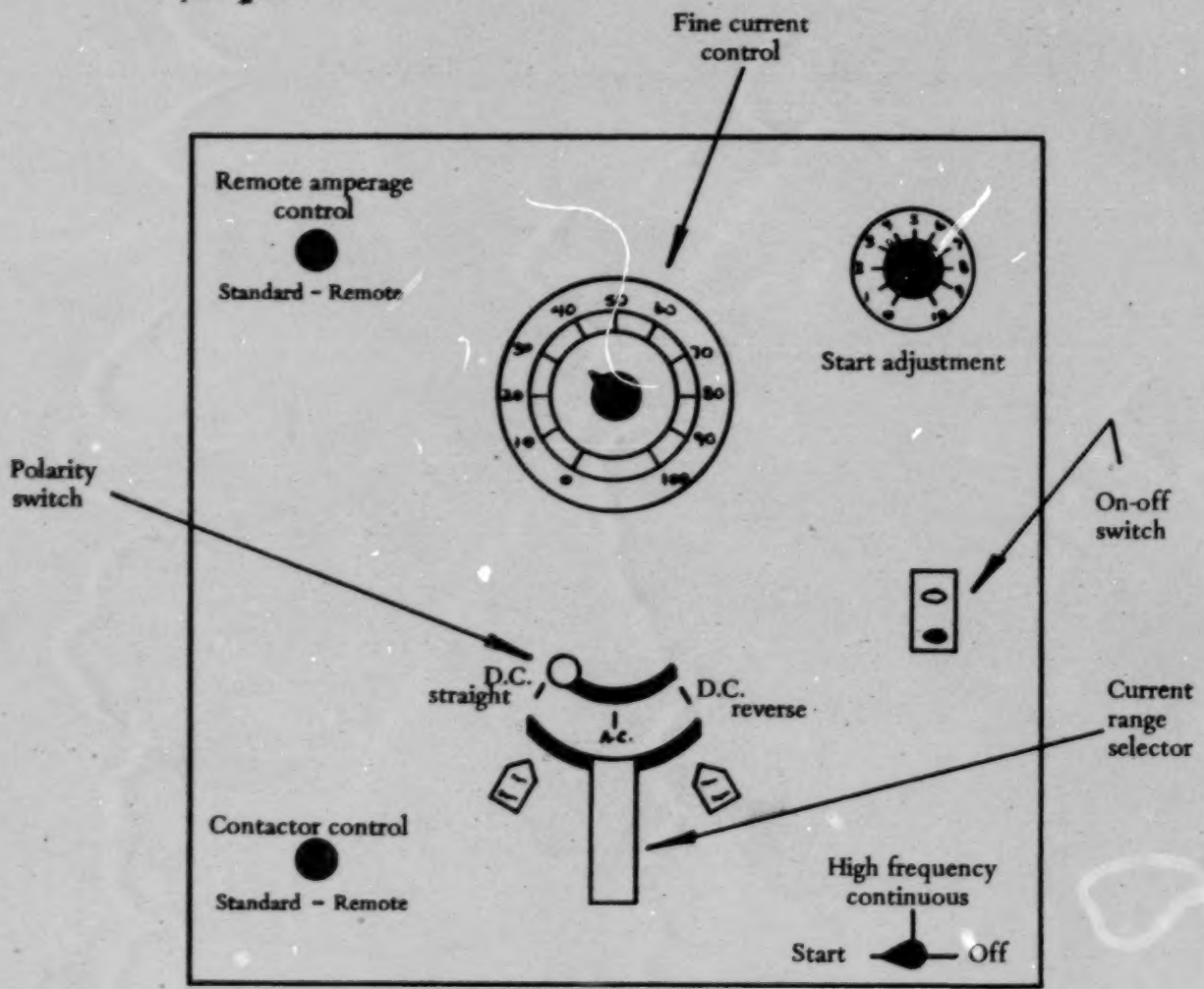
5. What kind of power is used to weld aluminum and its alloys?
   a. D.C.S.P.
   b. A.C.

TIG welding equipment is different than electric arc welding equipment. A torch, remote current control, inert gas flowmeter, inert gas cylinder, water tank, and ground clamp are needed.



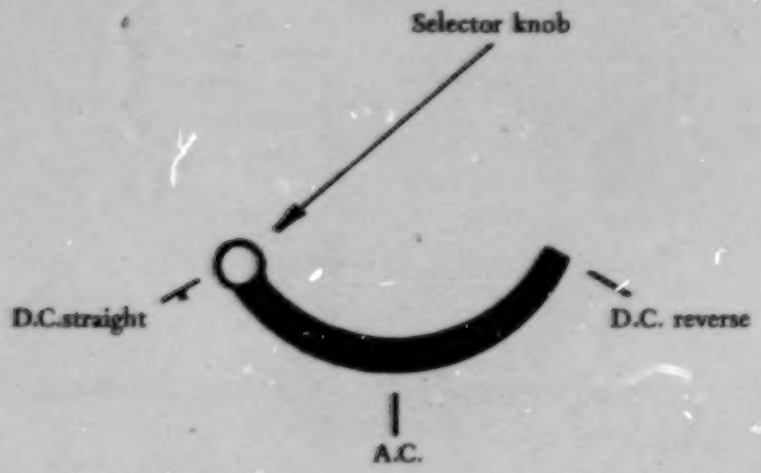
TIG welding equipment

The TIG power supply is not like the electric arc power supply. The difference is in the electrical parts. The TIG power supply contains more parts. It has a remote amperage control, fine current control, start adjustment, polarity switch, on-off switch, contactor control, current range selector, and a high frequency unit.



Face of Power Supply

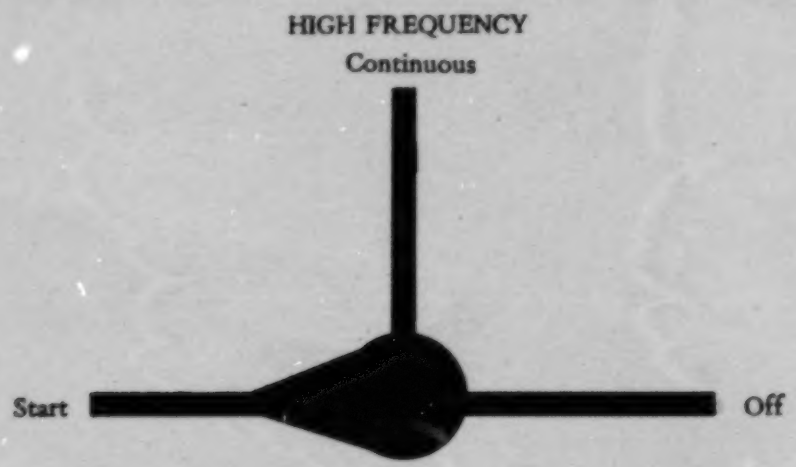
Adjust the welder before you start. Start the machine with the on-off switch. Then choose the kind of electric current for the metal. You have a choice of direct current straight polarity, alternating current, or direct current reverse polarity.



Polarity Switch

Choose the kind of electric current for the metal being welded. Use A.C. power for welding aluminum. Use direct current straight polarity for stainless steel.

You have selected the kind of electric current. Now set the high frequency switch. Set the switch to continuous high frequency for welding aluminum. Set the switch on start for welding stainless steel.

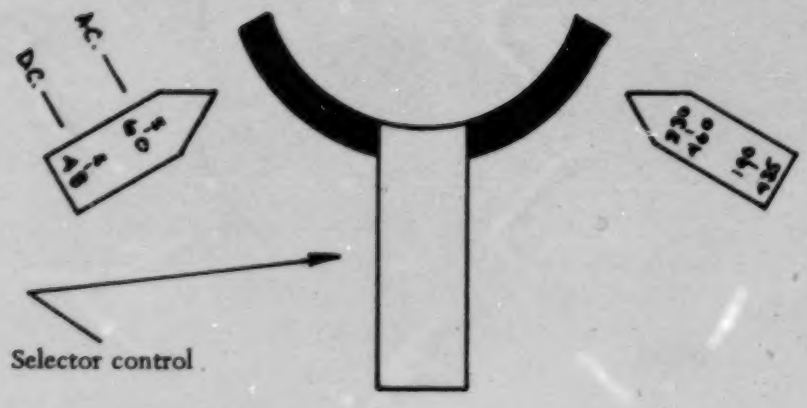


High Frequency Switch

When welding aluminum, we set the polarity switch to A.C. and the high frequency switch to CONTINUOUS. Set the polarity switch to D.C. STRAIGHT POLARITY and the high frequency switch to START when welding stainless steel.

The current range selector must now be set. In each range there are two sets of numbers. One set is for welding with A.C. power; and the other set is for D.C. power.

Current Range Selector



The range is determined by the size of the tungsten electrode. Each electrode can carry a certain amount of power. If too much power is used, the electrode will melt.

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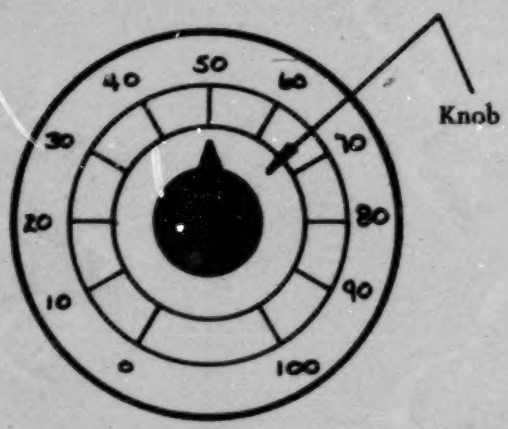
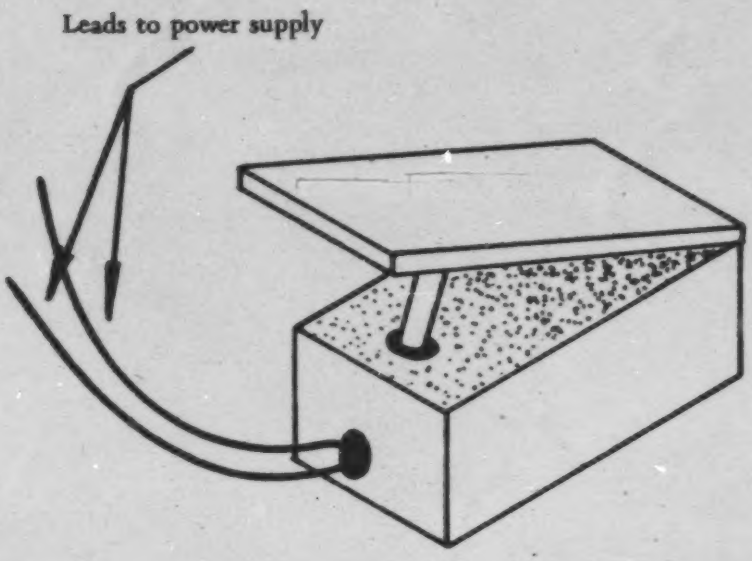
The fine current control is for small adjustments in the current range. Each number is a percentage of the current range. You can select 100% or less depending on how much current you need.



Fine Current Control

The diameter of the tungsten electrode determines where to set the fine current control. Too much current causes the tungsten to melt and become part of the weld. This causes a weak weld.

Most TIG welders have a remote current control. The remote current control is used to decrease or increase the power when welding. This control may be on the torch, or it may be a foot control. We will discuss the foot control.



Remote Foot Control

The leads from the foot control are connected to the power supply. The remote foot control works like a gas pedal in a car. Press the pedal harder for more current. The remote foot control gives the welder extra control for welding. It is needed for high quality welds.

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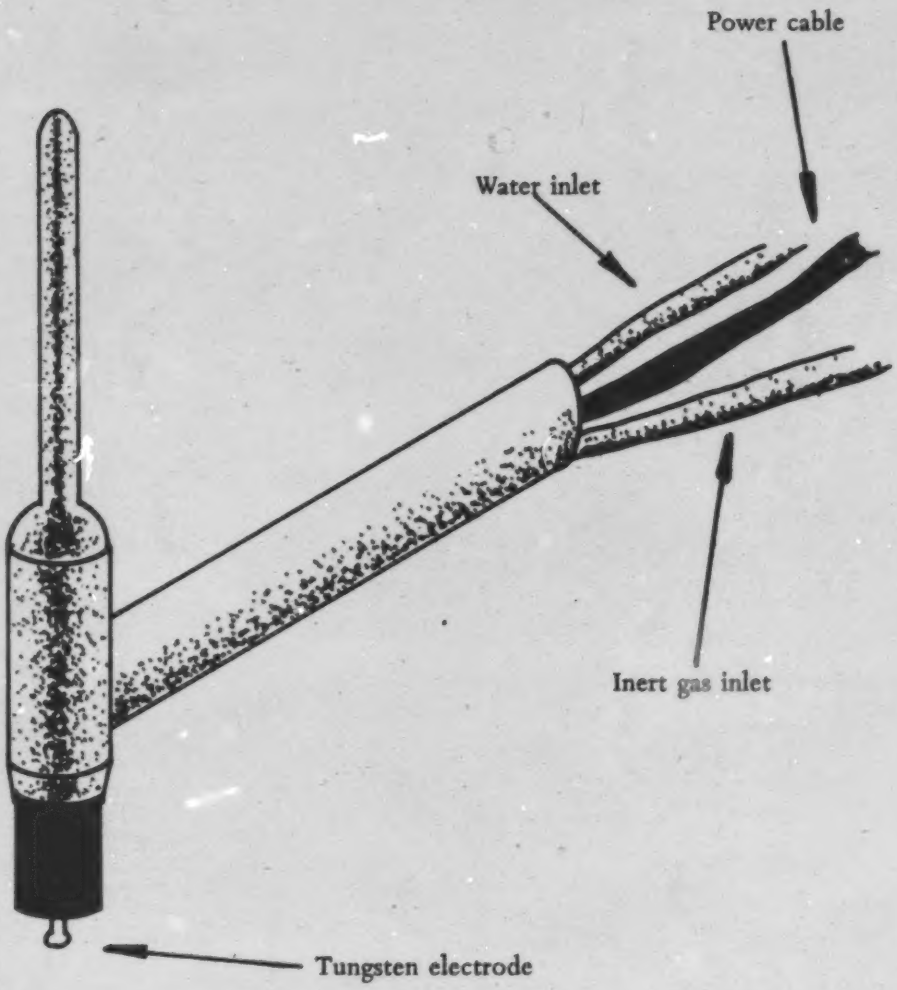
There are two kinds of TIG torches. One torch is water-cooled. The other torch is air-cooled. We will use only the water-cooled TIG torch now.

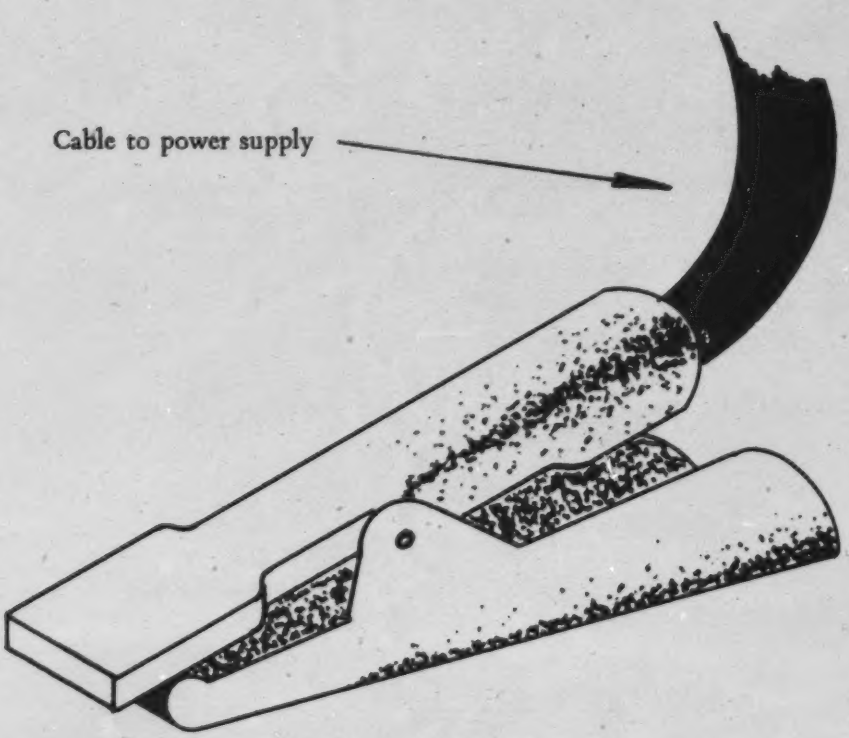
The TIG torch uses a tungsten electrode that can be used many times. Electrons going through the electrode heat the weldmetal to its melting point.



Water-Cooled TIG Torch

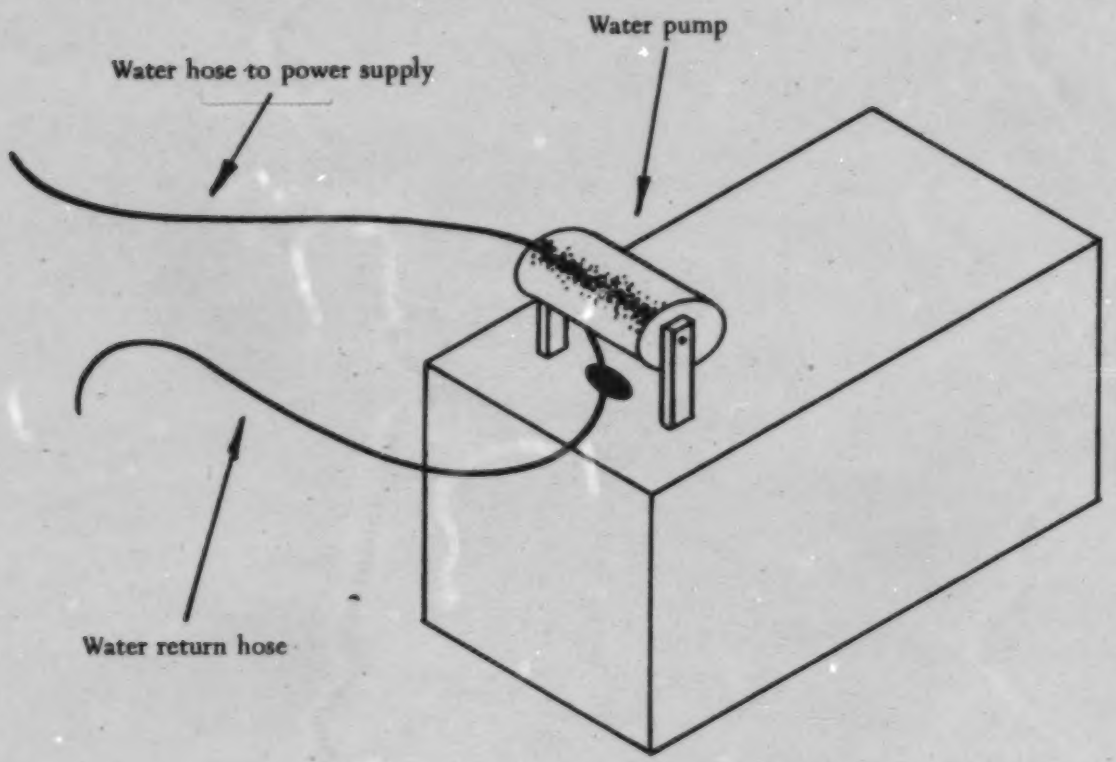
There are three leads connected to the water-cooled TIG torch. They are: (1) the power cable, (2) the inert gas hose inlet, and (3) the water hose inlet.

The ground clamp should be attached to the work. The ground clamp completes the electric circuit. You can't weld if the clamp is not attached to the work. Clean paint or other insulating materials from the work. Clean metal makes a good ground connection.



Ground Clamp

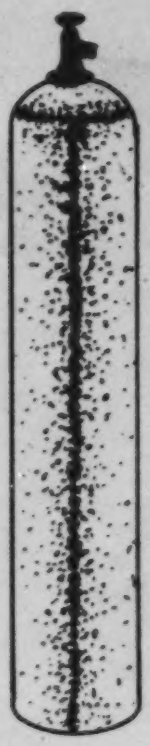
This is a water supply for a water-cooled torch. This system uses the same water over and over again. It recirculates the water.



Water Tank

The water goes from the water tank to the torch. The water cools the torch. Then it goes back to the water tank by the water return hose.

TIG welding uses inert gas as a flux. This gas keeps the metal free from oxidation when welding. It is stored in a cylinder.

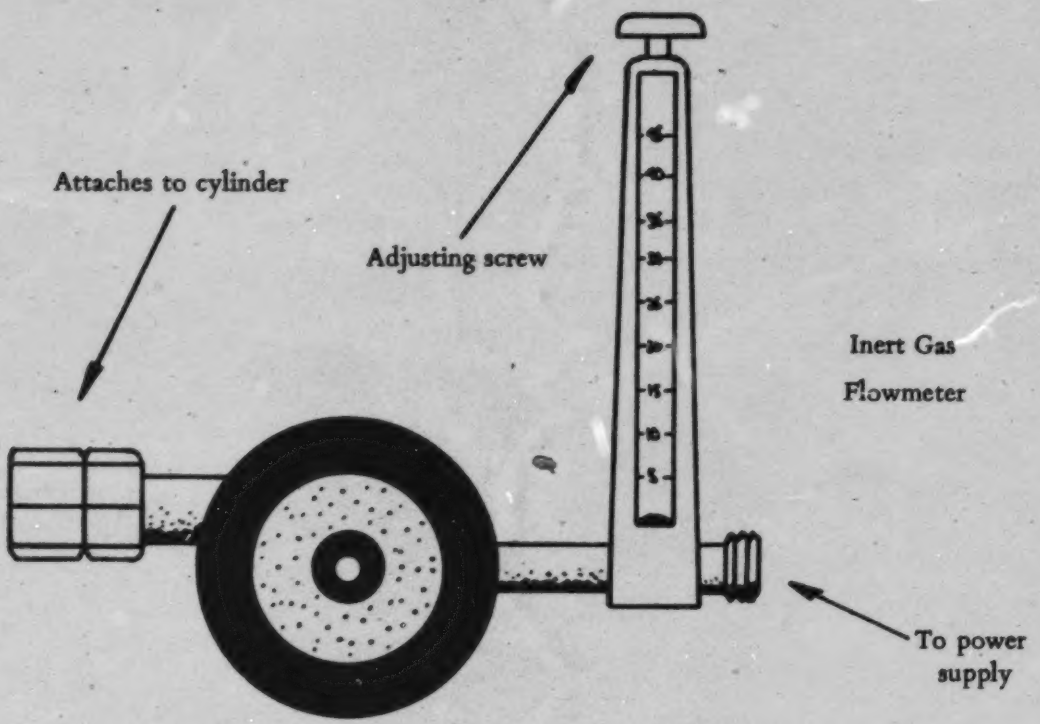


Inert gases
Argon
Helium

Inert gas
cylinder

Argon is the most popular inert gas for TIG welding. Helium is also used as an inert gas. The selection of an inert gas depends on the kind of metal and the quality of the job. A mixture of argon and helium are used for some jobs. Small percentages of oxygen are also added for some jobs.

The flowmeter controls the inert gas as the gas leaves the cylinder. The flowmeter is screwed onto the cylinder. A hose from the flowmeter sends the gas to the power supply. The power supply allows the gas to flow when you are welding.



The amount of gas needed for welding depends on the size of the tungsten electrode and the metal being welded. This gas flow is regulated by the adjusting screw on top of the flowmeter.

REVIEW

TIG welding equipment is easy to operate. Use a 1-2-3 approach to setting up the equipment.

1. Turn on the power.
2. Set the polarity switch and high frequency switch for the metal being welded.
3. Select the right current range for the tungsten electrode.
4. Set the fine current control. The current should be less than the current range of the tungsten electrode.
5. Check the foot control. The remote amperage control should be on remote.
6. Open the valve on inert gas cylinder. Adjust the flow of gas with the adjusting screw.
7. Is the water pump on? The torch will be ruined if it does not get water.

Practice the 1-2-3's of setting up the equipment in the shop.

QUESTIONS

1. Which of the following is *not* a part of the power supply?
   a. current range selector
   b. high frequency switch
   c. flowmeter
   d. polarity switch

2. What is used to select proper current for a welding job?
   a. high frequency switch
   b. polarity switch
   c. fine current control

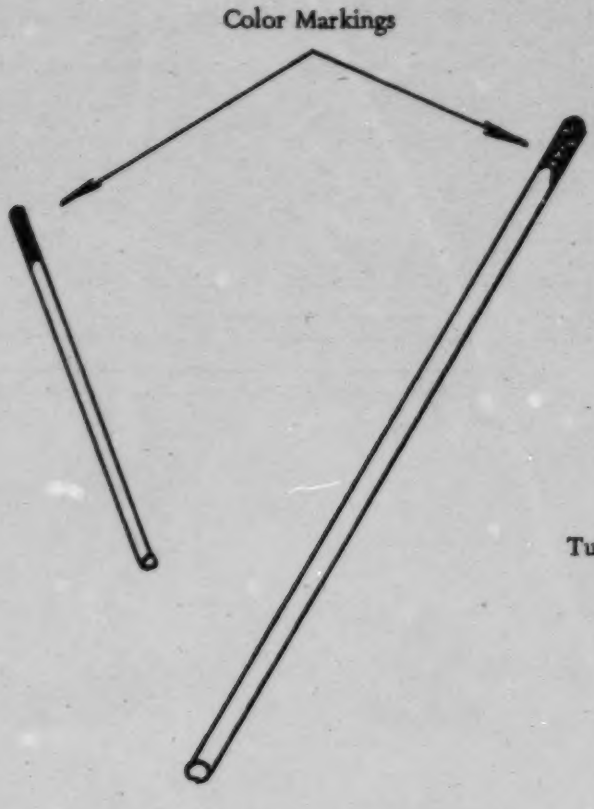
3. What determines the current range?
   a. kind of inert gas
   b. on-off switch
   c. size of tungsten electrode

4. What can be used to increase or decrease current when welding?
   a. remote foot control
   b. tungsten electrode
   c. polarity switch

5. What is used to cool the torch?
   a. inert gas
   b. ground clamps
   c. water

6. What is used to control inert gas flow from the cylinder?
   a. torch
   b. flowmeter
   c. water pump

Different tungsten electrodes are selected for different welding jobs. Some electrodes are almost pure tungsten. These electrodes are best for welding aluminum. Some tungsten electrodes have small amounts of thoria or zirconium. The electrodes with thoria are used for direct current straight polarity welding.

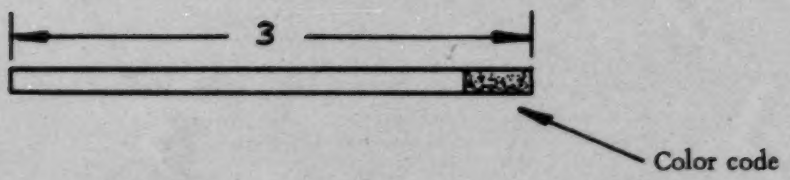


Tungsten Electrodes

The color markings show you what the electrode is made of. Learn your color markings.

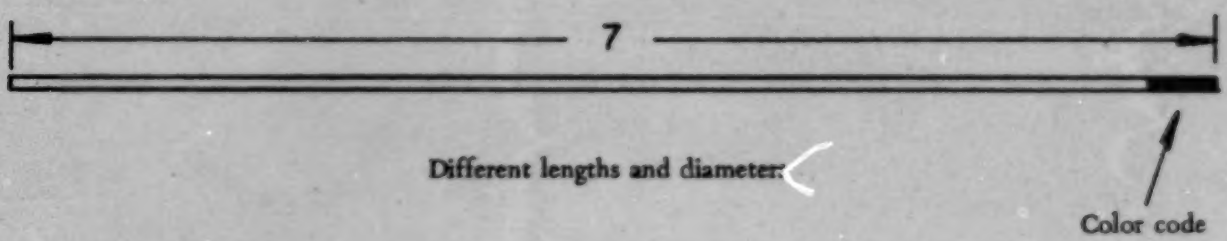
Each kind of electrode is color coded.

- Pure tungsten is green.
- 1% thoriated tungsten is yellow.
- 2% thoriated tungsten is red.
- Zirconium-treated tungsten is brown.



Learn the color codes of each kind of electrode. Then learn when to use each kind of electrode.

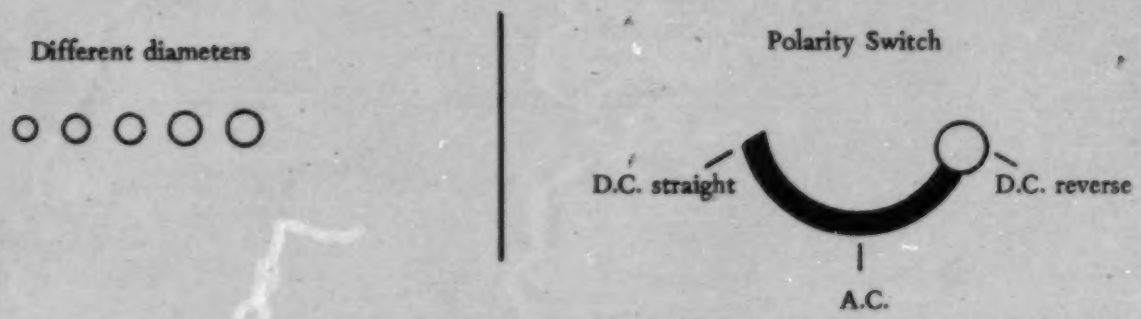
Tungsten electrodes are sold in different lengths and diameters. The lengths of the electrodes are from 3" to 24". The most common lengths for TIG welding are 3" and 7".



Different lengths and diameters

The electrode diameters that you will need are .040", 1/16", 3/32", 1/8", and 5/32". Each length of electrode is sold in any of these diameters.

The diameter of the electrode and the kind of electric power are important power control factors.



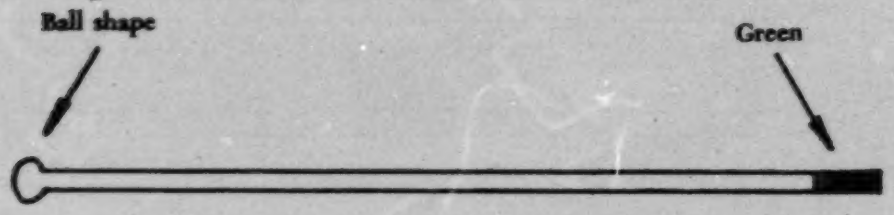
Power control factors

The electrode with the largest diameter will carry the most electric current. A 1/8" electrode will carry more current than a 1/16" electrode.

The kind of power changes the amount of current that an electrode will carry. For example, a 1/16" electrode will carry:

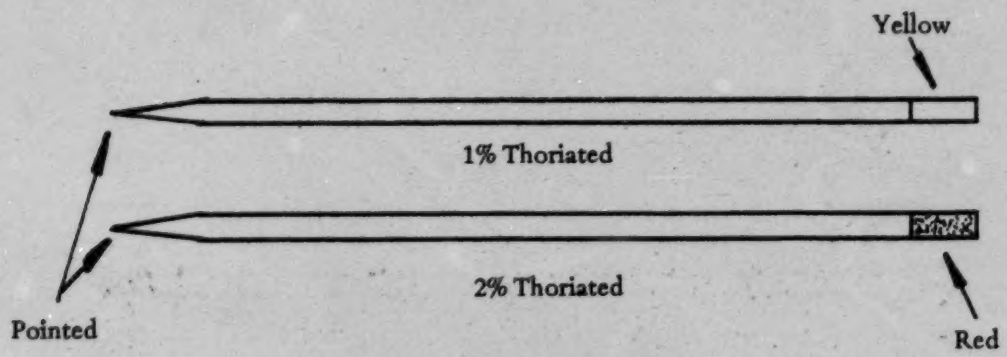
- 100 amps of direct current straight polarity (D.C.S.P.)
- 50 amps of direct current reverse polarity (D.C.R.P.)
- almost 100 amps of A.C.

Use a pure tungsten electrode for welding aluminum. Pure tungsten balls up better than thoriated tungsten. A good ball shape is needed when using A.C. power. Remember, the color on the end of a pure tungsten electrode is green.



Pure tungsten - for aluminum

Use a thoriated tungsten electrode for welding stainless steel.



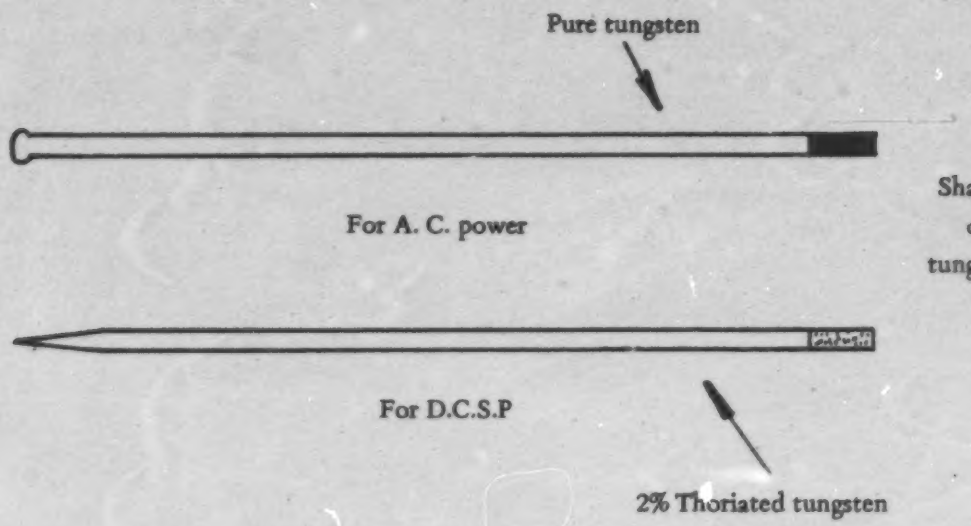
Thoriated tungsten - for stainless steel

The thoriated tungsten is best for any kind of metal when you use direct current straight polarity (D.C.S.P.). The thoriated tungsten gives a better flow of electrons. Remember, the colors are:

- 1% thoriated tungsten - yellow
- 2% thoriated tungsten - red

The shape of the electrode is important. The end of the electrode should be:

- ball shaped with A.C. power.
- pointed with D.C.S.P.

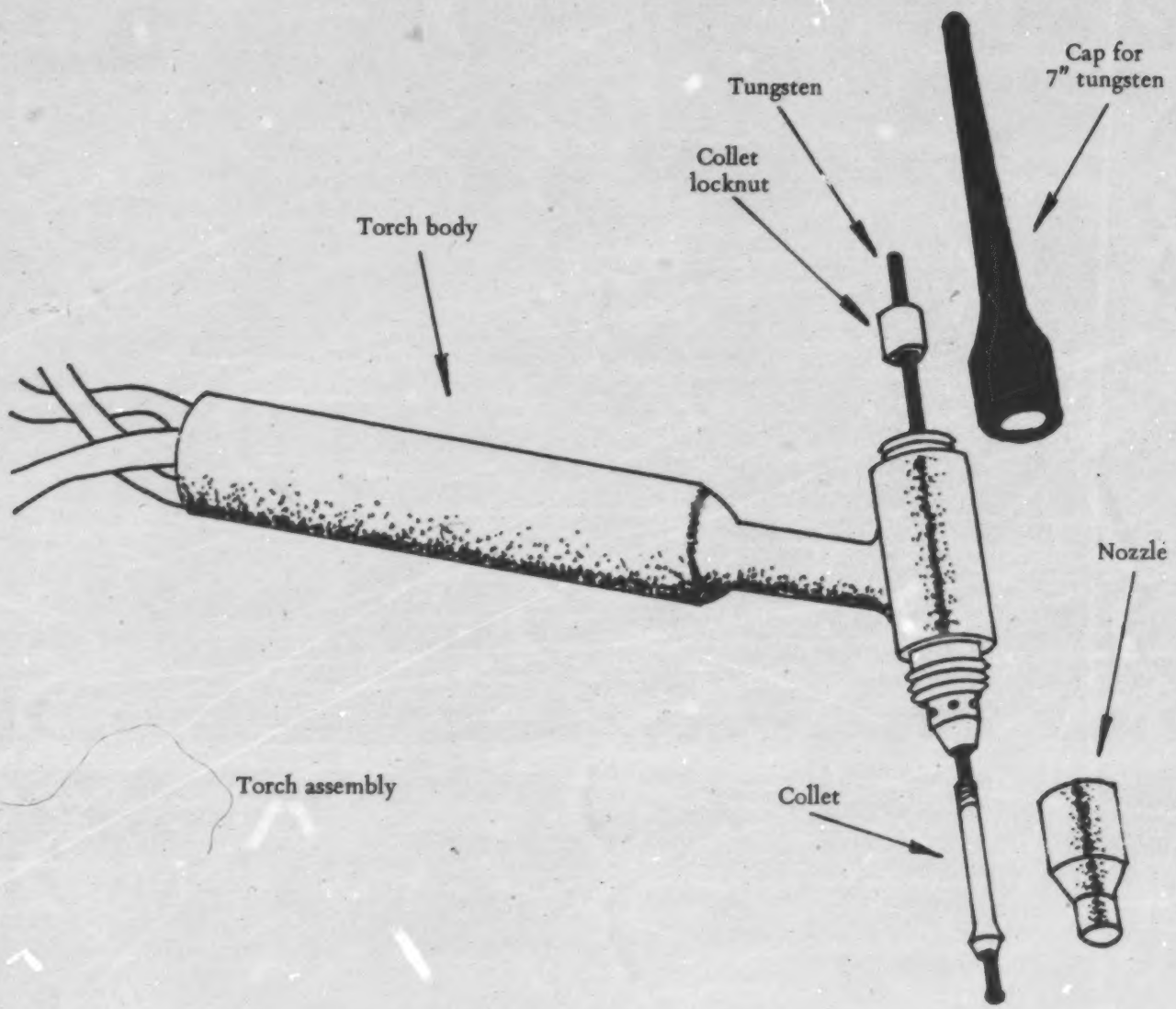


Shapes of Tungsten

The correct shape of the tungsten allows a better flow of electrons for the different kinds of power.

Remember, use pure tungsten electrodes with A.C. power. Use thoriated tungsten electrodes with D.C.S.P.

The tungsten electrode is held by the torch. A collet holds the tungsten in place. There is a different collet size for each electrode diameter.



Each collet will hold only one size tungsten electrode correctly. If a tungsten does not go through the collet easily, do not force it. When the lock nut is tight and the electrode falls out, the collet is too small.

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Tungsten electrodes have a code classification that was developed by the American Welding Society (A.W.S.). The code is:

- EWP - pure tungsten
- EWTH-1 - 1% thoriated tungsten
- EWTH-2 - 2% thoriated tungsten

Different electrodes have different characteristics.

- Pure tungsten melts at 6170°F.
  It is best for welding aluminum.

- Thoriated tungsten has a higher melting point than pure tungsten.
  Thoriated tungsten electrodes are best for welding stainless steel.
  It is also used for welding other metals with D.C.S.P. current.

Do you remember the color codes for tungsten electrodes?

- Green - pure tungsten
- Yellow - 1% thoriated tungsten
- Red - 2% thoriated tungsten
- Brown - zirconium-treated tungstens

Tungsten electrodes come in standard sizes from 3" to 24" lengths. What are the two most common sizes for TIG welding? Yes, the 3" and 7" lengths are the most common.

Can thick electrodes handle more power than thin electrodes? The answer is yes. An electrode with a 1/8" diameter will carry more current than a 1/16" diameter electrode.

Does the kind of power change the amount of power that can be used? The answer is yes. For example, a 1/16" electrode will carry:

- 100 amps of D.C.S.P.
- 50 amps of D.C.R.P.
- almost 100 amps of A.C.

REVIEW

- Different tungsten electrodes are used for welding different metals.
    - Pure tungsten electrodes are for aluminum.
    - Thoriated tungsten electrodes are for stainless steel.

- The color codes on the electrodes are:
    - green for pure tungsten.
    - yellow for 1% thoriated tungsten.
    - red for 2% thoriated tungsten.
    - brown for zirconium-treated tungsten.

- Ball-shaped electrode ends are used with A.C. power.

- Pointed-tip electrodes are used with direct current straight polarity (D.C.S.P.) power.

- Use the correct size of collet to hold each size of electrode.

QUESTIONS

1. TIG welding electrodes contain more of _____ than any other metal.
   a. thoria
   b. tungsten
   c. zirconium

2. Tungsten electrodes come in different _____ and _____.
   a. diameters and lengths
   b. sizes and power
   c. alloys and tastes

3. What is the end color of pure tungsten?
   a. red
   b. brown
   c. yellow
   d. green

4. What kind of electrode should be used for welding stainless steel?
   a. pure tungsten
   b. thoriated tungsten
   c. zirconium-treated tungsten

5. What shape for the end of the electrode should be used for welding with A.C. and a pure tungsten electrode?

   a. ball
   b. pointed
   c. blunted

6. How is the electrode held in the torch?

   a. with a wrench
   b. with a cap
   c. with a collet

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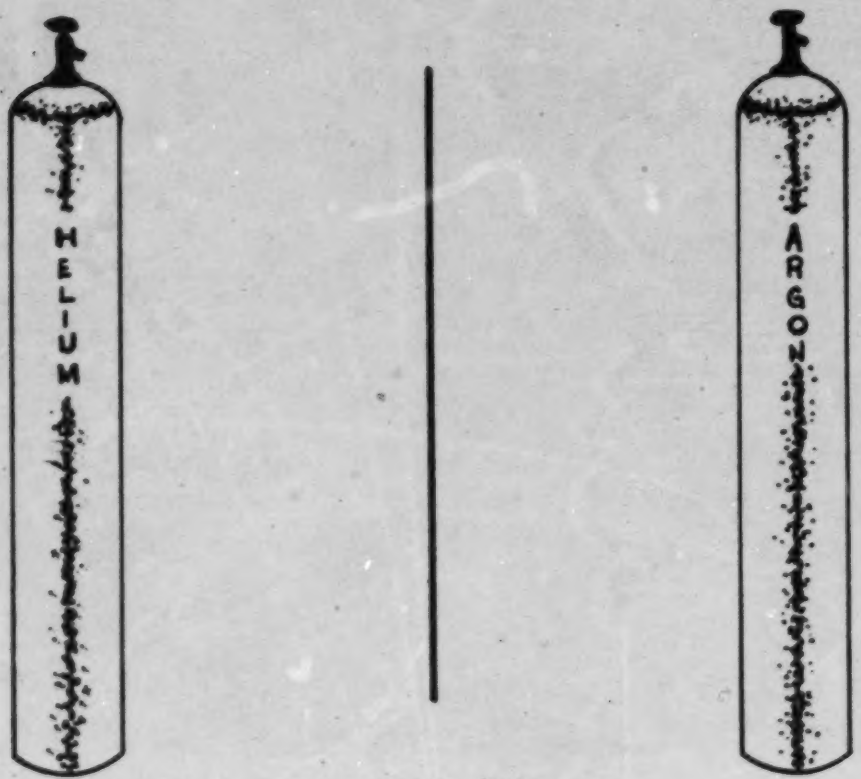
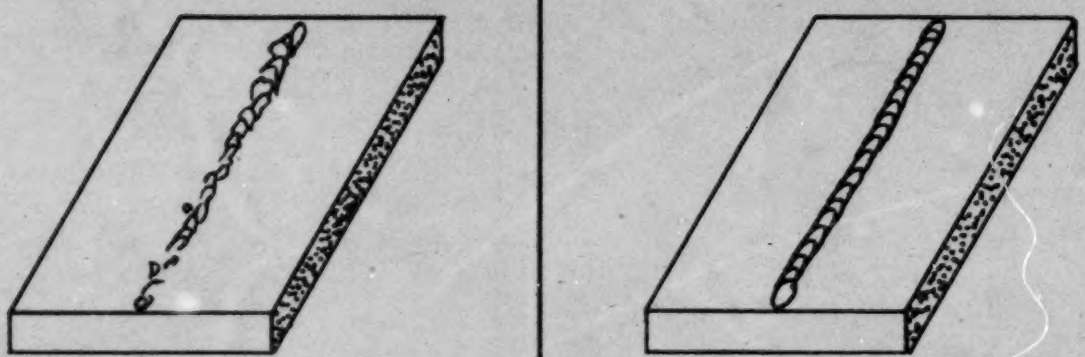
Inert gas is a flux. It protects the welding puddle from air, dirt, and other contamination. The gas pushes the air out of the welding area.



Inert gas in cylinders

Argon and helium are the inert gases used for TIG welding. A mixture of both argon and helium may be used. Welders use argon more than helium.

Argon prevents contamination. It pushes air out of the welding area. A good weld is strong. It also looks good.

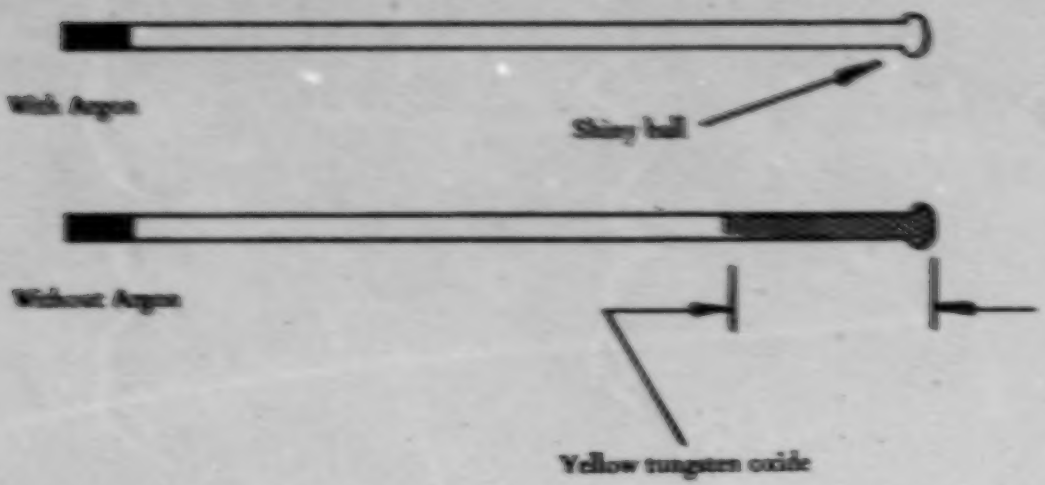


Weld made without Argon

Weld made with Argon

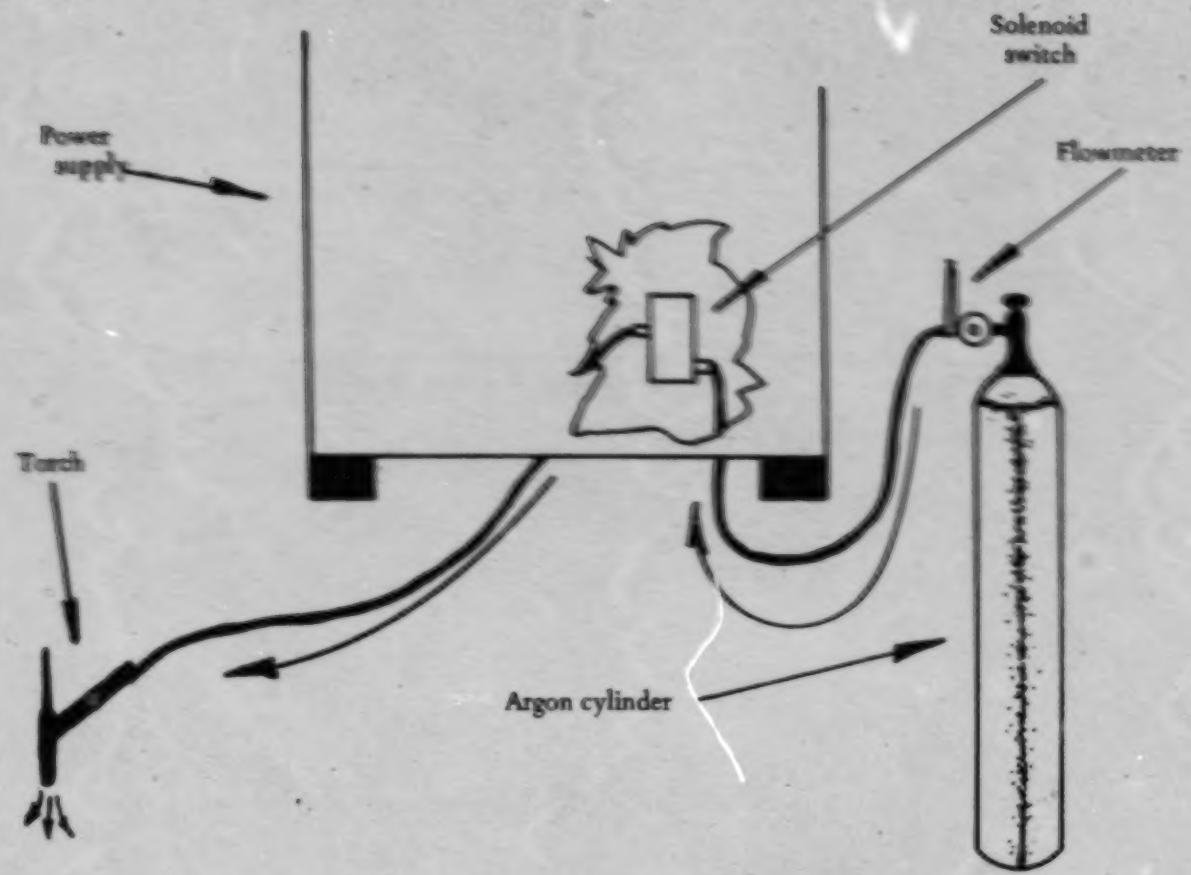
Argon keeps oxygen away from the metal. Oxygen causes oxides to form. Oxides cause the weld to become brittle and weak. Inert gases help make the weld strong; they prevent oxides.

The inert gas prevents oxidation of the tungsten electrode. Look at the tungsten electrode. Oxidised tungsten electrodes have a yellow powder on them. The yellow powder is tungsten oxide.



The tungsten electrode will have a shiny ball on the end when argon is used. The argon prevents tungsten oxidation.

Argon flows from the cylinder to the power supply. Then it flows from the power supply to the torch. The flow of gas is controlled by the flowmeter.

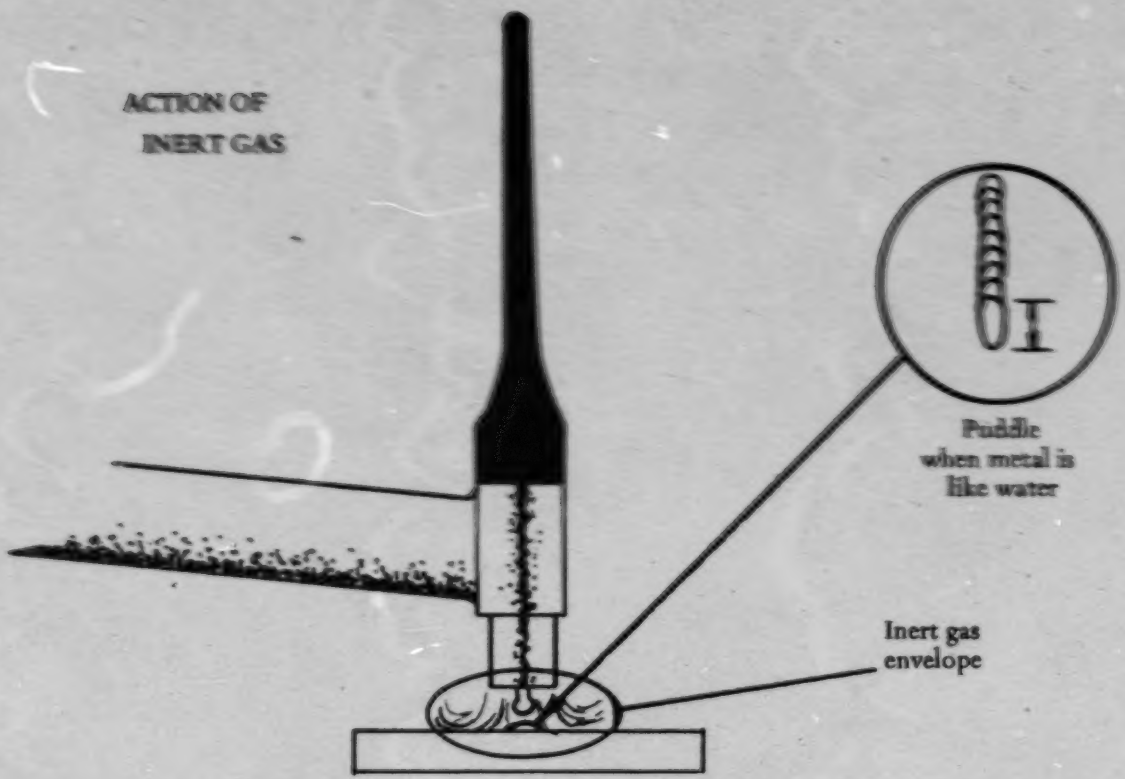


Path of Argon

The amount of gas needed depends on the:

- diameter of the tungsten
- thickness of the metal
- weld position

The inert gas protects the weld. It pushes the air away from the puddle. The puddle is the pool of molten metal made from the heat of the arc. It looks like water.

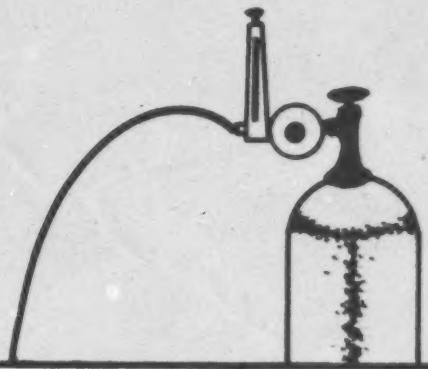


The area that is filled with inert gas is called the envelope. The gas envelope protects the weld. The electrode oxidizes if there isn't enough gas. The oxidation looks like a yellowish material near the end of the electrode.

The flow of inert gas is controlled by a flowmeter. The gas does not flow all of the time. It flows when you have a welding arc. It also flows for a short time after the arc has been broken. The rate of flow is measured in cubic feet per hour (C.F.H.). The amount of flow depends on:

- thickness of metal
- kind of metal
- diameter of tungsten electrode

This chart shows how much argon to use when welding in the flat position. The flow rate is increased when welding in horizontal, vertical, and overhead positions.



ALUMINUM			STAINLESS STEEL		
Pure Tungsten Electrode Diameter	Thickness of Metal in Inches	Flow Rate for Argon (C.F.H.)	Thoriated Tungsten Electrode Diameter	Thickness of Metal in Inches	Flow Rate for Argon (C.F.H.)
1/16	1/16	15 to 20	1/16	1/16	11
3/32	1/8	17 to 25	1/16	3/32	11
1/8	3/16	21 to 30	1/16	1/8	11
3/16	1/4	25 to 35	3/16	3/16	13
3/16, 1/4	3/8	29 to 40	1/8	1/4	13
3/16, 1/40	1/2	31 to 40	3/16	1/2	15

Argon is the most popular inert gas. You can't see, taste, or smell it.

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What does TIG mean? The name TIG comes from the first letters of the following words. 'T' means tungsten. Tungsten electrodes are used for TIG welding. The 'I' is inert, and the 'G' is gas. Inert gas protects the weld from oxidation.

REVIEW

- Inert gas protects the weld from oxygen.
- Oxidized tungsten electrodes have a yellow powder on the ends.
- Tungsten electrodes have shiny ends when the flow of inert gas is correct.
- Argon is the most popular inert gas.
- The amount of inert gas depends on: (1) the diameter of the tungsten, (2) the thickness of the metal, and (3) the kind of metal.

QUESTIONS

1. The purpose of the inert gas is_____.
   a. to be stored in cylinders.
   b. to protect the welding puddle.
   c. to mix with helium.

2. Argon is an inert gas that pushes_____ out of the work area?
   a. air
   b. helium
   c. tungsten

3. What happens to the tungsten when welding without argon?
   a. A shiny ball forms.
   b. A weld forms.
   c. A yellow oxide forms.

4. The area around the weld filled with inert gas is called_____.
   a. the puddle.
   b. the envelope.
   c. air contamination.

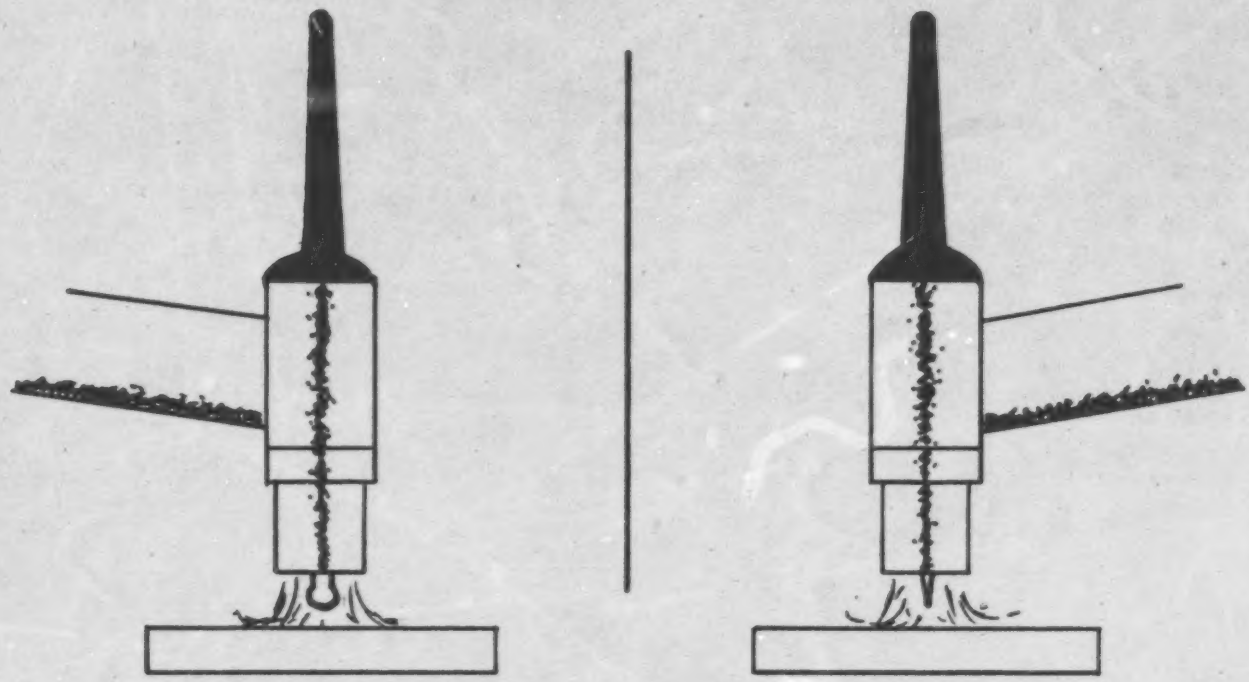
5. The rate of inert gas flow is measured in _____.

   a. cubic feet per hour (C.F.H.)
   b. electron flow.
   c. polarity, either A.C. or D.C.

6. The _____ does not determine the rate of inert gas flow.

   a. diameter of the electrode
   b. thickness of the metal
   c. kind of metal
   d. polarity of the power supply

The action of the arc is different with A.C. power than with D.C.S.P. power. Remember, the electrons flow in one direction with D.C. power. The electrons flow in both directions with A.C. power. The D.C.S.P. arc is much smoother than the arc made with A.C. power.

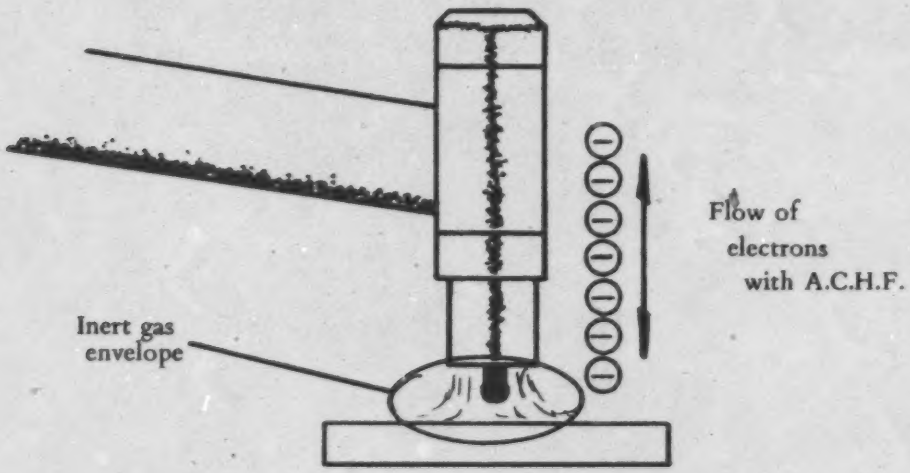


A.C. Arc

D.C.S.P. Arc

You will use different arcs for different uses.

Continuous high frequency A.C. power is often used. The continuous high frequency is called A.C.H.F. for alternating current, high frequency. The A.C.H.F. arc is much rougher than a D.C.S.P. arc. It is rougher because the electrons are flowing in two directions.



The A.C.H.F. welding arc may move around. The arc moves around more when the electrode is dirty. Clean the electrode. The arc will also move around if: (1) the inert gas envelope is disturbed, or (2) not enough inert gas is flowing.

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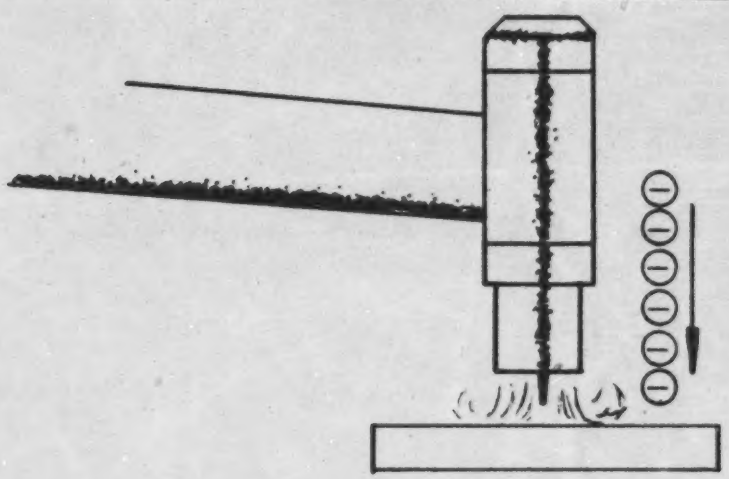
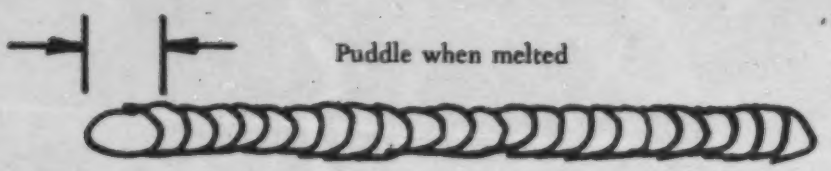
A high frequency start is used with D.C.S.P. The high frequency start makes it easier to start the welding arc. The D.C.S.P. arc is smooth because the electrons flow in one direction. The electrons flow from the torch to the work.



Flow of electrons with D.C.S.P.

The thoriated tungsten electrode is used for D.C.S.P. It is ground to a point. The point helps concentrate the electrons to one point. The point makes it easier to puddle the metal. Prevent a rough, uncontrolled arc. Use a pointed electrode with D.C.S.P.

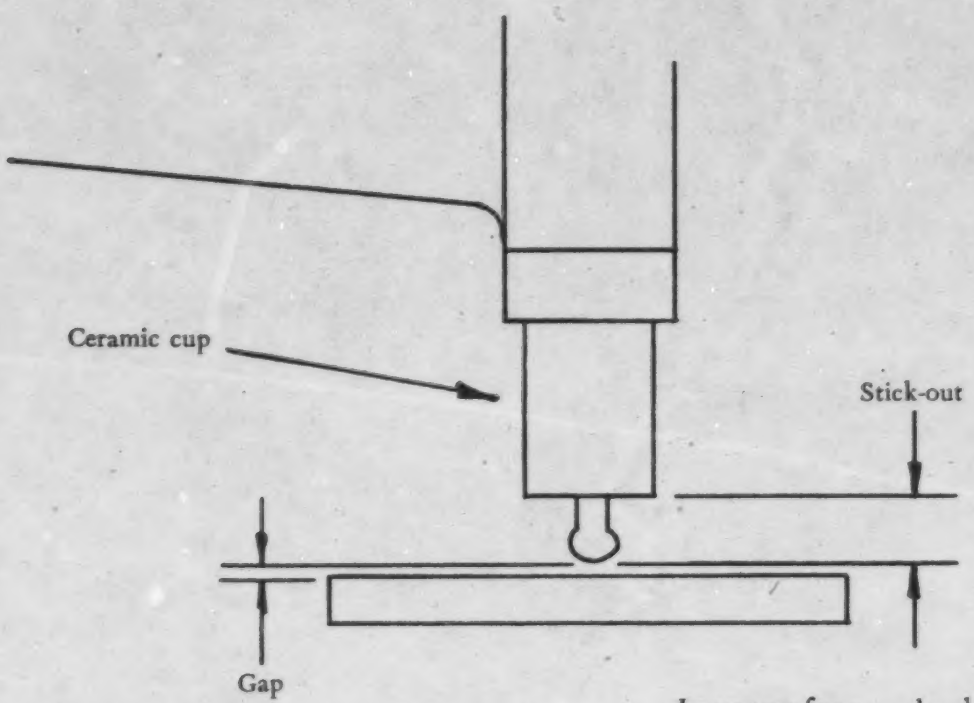
A puddle forms when metal melts. The melted metal becomes a liquid. It flows like water, but it is very hot. The electrical power needed to puddle metal depends on the thickness of the metal. Thick metal requires more power than thin metal.



Good weld

After the puddle is formed, the torch must be moved along the work at an even rate. Keep the electrode the same distance from the work for the entire weld.

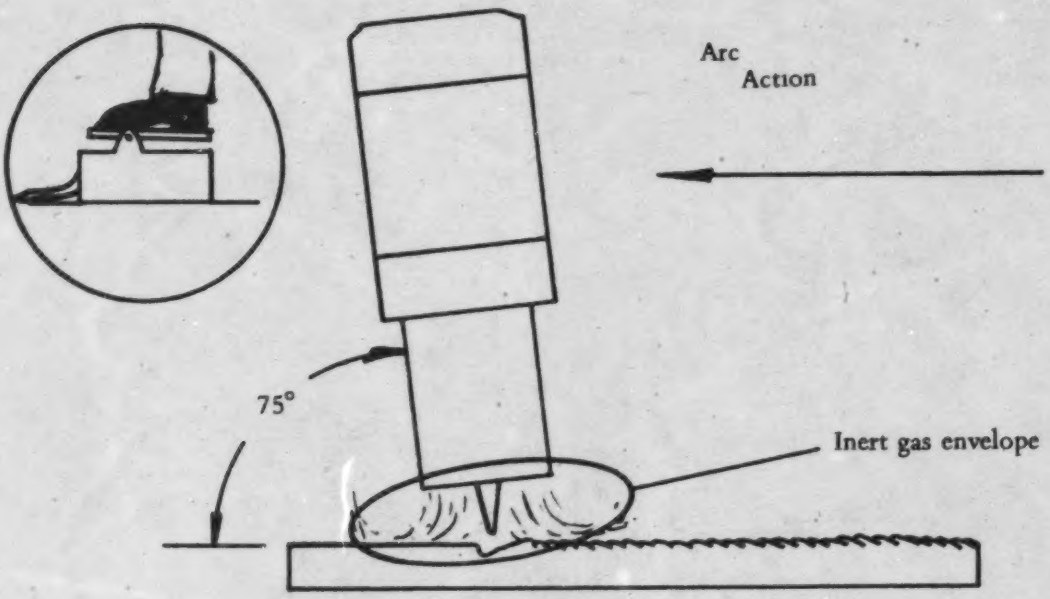
Look at the drawing. The gap is the distance from the end of the electrode to the work. This gap should be the same for the entire weld. The gap should not be larger than the diameter of the electrode.



Important for a good weld

Look at the electrode stick-out on the drawing. This is the distance that the electrode extends past the ceramic cup. The electrode stick-out differs with the welding position. It should not be greater than 3/16" for flat welds, 1/4" for horizontal fillets, and 1/8" for corner welds. Yellow tungsten oxide forms when the electrode sticks out too much.

TIG welding gives a brighter arc than stick welding. It is brighter because there is no flux to burn or smoke. The puddle can be seen easier because of the bright arc. This makes it easier to control the puddle for a good weld.



The torch should be slanted at a slight angle in the direction of the weld. After the arc has been established, the foot control should be pressed down until a puddle is formed. The puddle will be almost directly under the electrode.

REVIEW

- The TIG arc is smooth and moves around less with D.C.S.P. current than with alternating current, high frequency (A.C.H.F.).

- The TIG arc is cleaner and brighter than an arc with a stick electrode. The light makes it easier to see and control the puddle for a good weld.

- The welding gap and electrode stick-out are important for a good weld. Check for the correct gap and electrode stick-out for each job.

- Slant the torch in the direction of the weld.

- The arc melts the metal and welds the pieces of metal together.

QUESTIONS

1. Which produces the smoothest arc?
   a. A.C.H.F. current
   b. D.C.S.P. current
   c. D.C.R.P. current

2. What is used with A.C. power most often when TIG welding?
   a. high frequency
   b. electrons
   c. gas envelope

3. When the electrons flow from the torch to the work, what kind of current is used?
   a. A.C.H.F.
   b. D.C.R.P.
   c. D.C.S.P.

4. What protects the weld area during welding?
   a. high frequency
   b. electrons
   c. gas envelope

5. What is formed when the metal reaches its melting point?
   a. puddle
   b. electrons
   c. power

6. What is the distance from the work to the electrode called?
    a. stick-out
    b. gap
    c. fillet

7. What is the distance that the electrode extends from the ceramic cup called?
    a. stick-out
    b. gap
    c. fillet

8. What makes the TIG arc brighter than the arc of stick electrode welding?
    a. the puddle
    b. slanted torch
    c. lack of smoke

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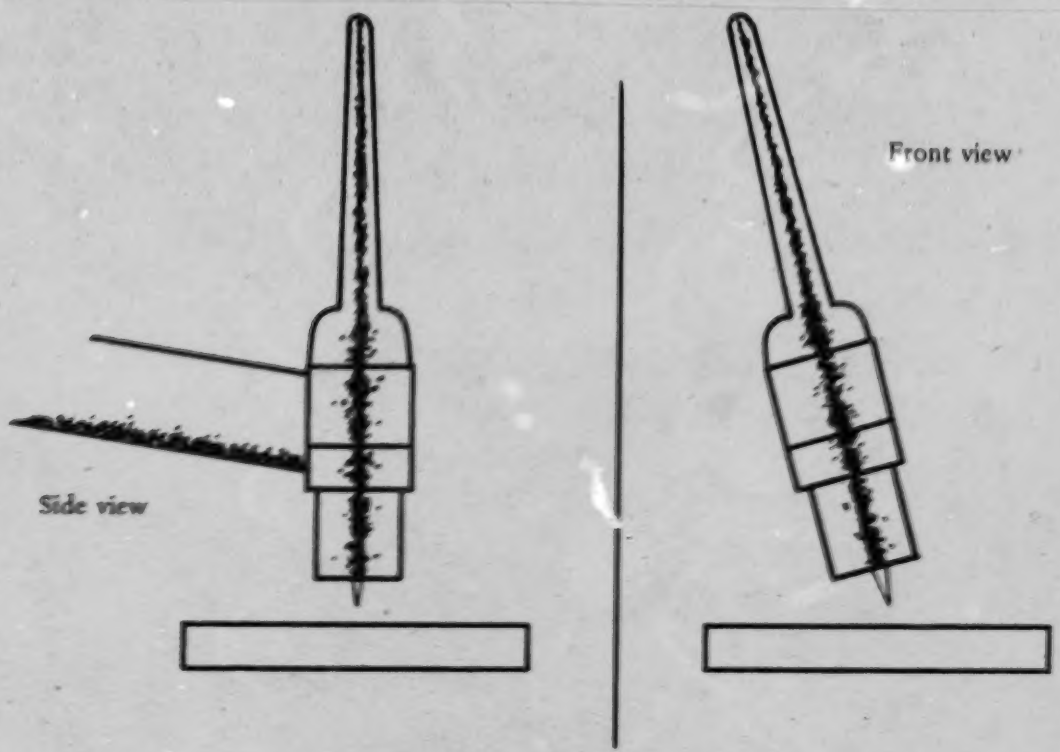
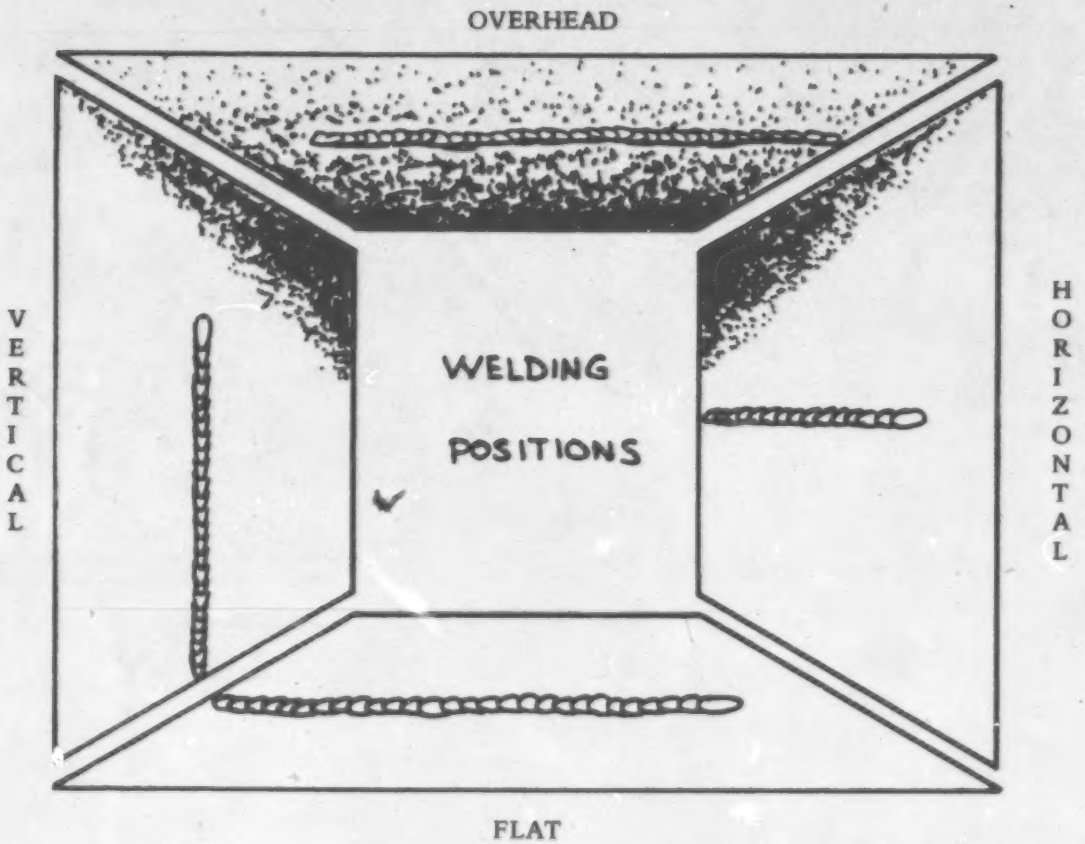
The torch position is important in making a good weld. For each welding position the torch position is different. The work is always under the torch when welding in the flat position.



The torch should be slanted slightly in the direction that you are welding. The electrode gap should remain the same when welding.

The four welding positions are (1) flat, (2) vertical, (3) overhead, and (4) horizontal.



The flat position is the easiest and most efficient position. The torch is held over the work in the flat position. Learn to weld in the flat position before you try the other positions.

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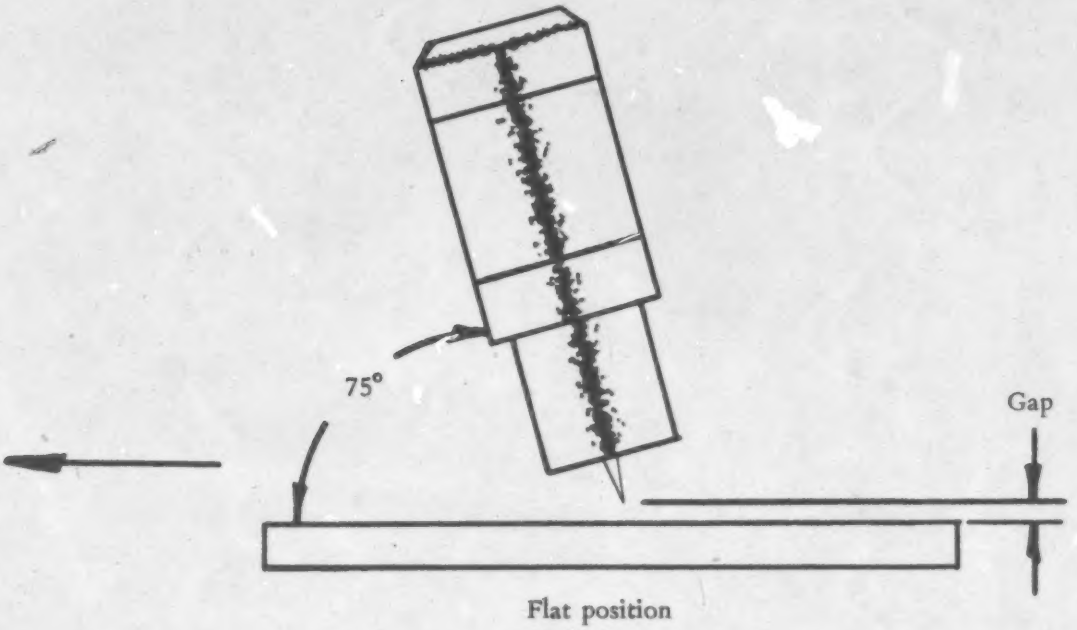
Slant the torch in the direction of the weld. The angle should be about 75° from the weld. The angle from the side should be 90°.



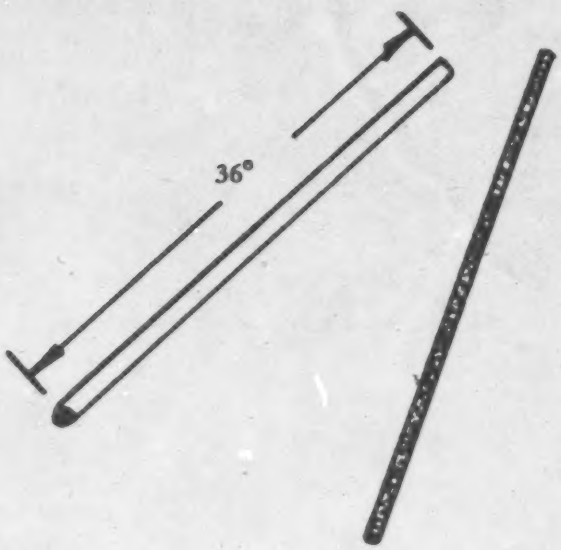
Flat position

Check the electrode gap. It should be equal to the diameter of the electrode. Keep the same gap for the entire weld.

The drawing above shows a pointed electrode. The pointed electrode is used with D.C.S.P. current. The angle and the gap would be the same if it was a ball-shaped tungsten electrode; the current would be different.

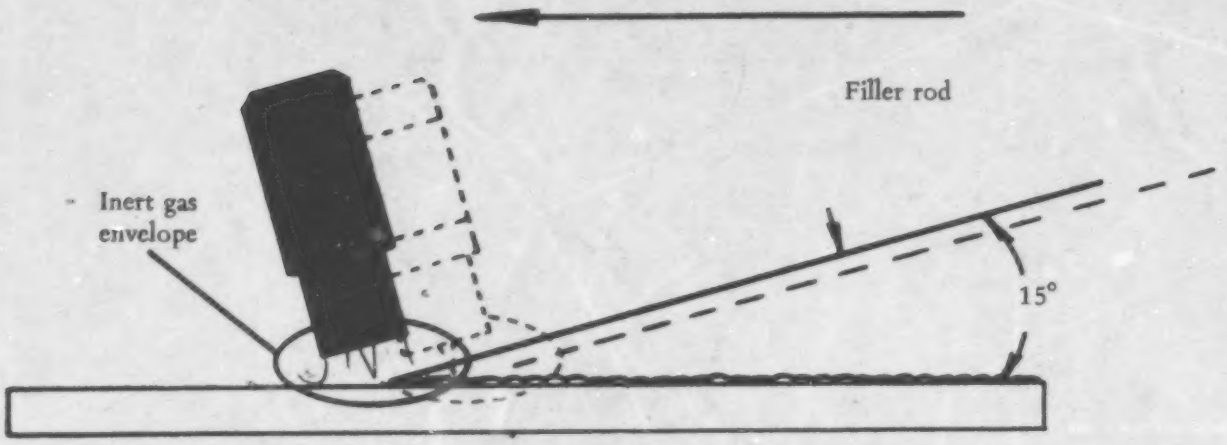
Hold the torch with one hand. The other hand is free to add filler metal when it is needed.

Filler metal is often used for TIG welding. Use the same kind of filler metal as the kind of metal being welded. Aluminum filler metal is used for aluminum, etc.



Filler metal is often called filler rod. It is usually 36" long and comes in different diameters. The diameter of the filler rod used depends on the thickness of the metal being welded.

Keep the end of the filler rod in the inert gas envelope. It should never leave the inert gas envelope between touches to the puddle. The filler rod should be kept at a 15° angle to the work.



Keep filler rod in inert gas envelope

It is important for the filler metal to stay in the inert gas envelope. Do not touch the filler rod to the electrode. If the filler rod touches the tungsten, the electrode may become contaminated. If the tungsten electrode becomes contaminated, it will have to be prepared for welding again.

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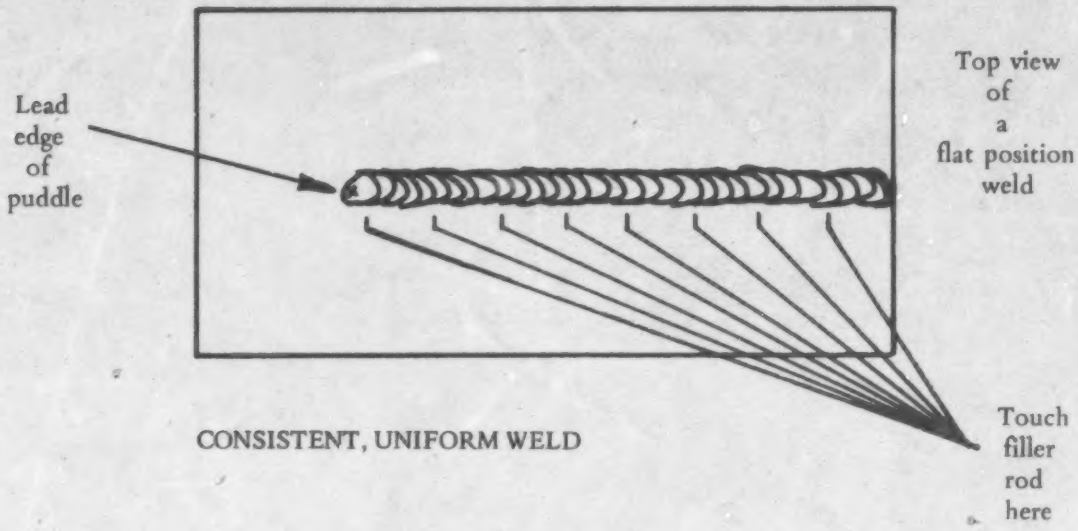
It is important to develop a rhythm when adding filler metal. The rhythm will produce a consistent, uniform weld. The rhythm used is up to the welder. One rhythm used is the 1-2-3 touch type. This amounts to a count of three before touching the metal. Repeat until the weld is completed.



CONSISTENT, UNIFORM WELD

In this illustration, the 'X' mark shows where the filler rod should touch the puddle. It is towards the lead edge. The lines show where filler metal should have been added. The lines are the same distance from each other. The weld made using a rhythm is uniform.

REVIEW

- The four welding positions are: (1) flat, (2) vertical, (3) overhead, and (4) horizontal.
- The flat position is the easiest and most efficient welding position.
- Slant the torch 75° in the direction of the weld.
- The electrode gap should be equal to the diameter of the electrode.
- The electrode gap should be the same for the entire weld.
- The angle and gap are the same for pointed electrodes and ball-shaped electrodes.
- The diameter of the filler rod depends on the thickness of the metal being welded.
- Keep the end of the filler rod in the inert gas envelope.
- Add filler metal with a rhythm for a uniform weld.

QUESTIONS

1. When welding in the flat position, where is the work?
   a. over the torch
   b. under the torch
   c. next to the torch

2. How many basic welding positions are there?
   a. three
   b. four
   c. five

3. The _____ should be held at a slight angle in the direction of the weld.
   a. tungsten
   b. ceramic cup
   c. torch

4. From the side view, what is the angle between the torch and the work?
   a. 90°
   b. 70°
   c. 75°

5. What is often used when TIG welding?
   a. stick electrode
   b. zirconium
   c. filler metal

6. What is the angle between the filler rod and the work?

   a. 90°
   b. 75°
   c. 15°

7. Where should the filler rod stay during welding?

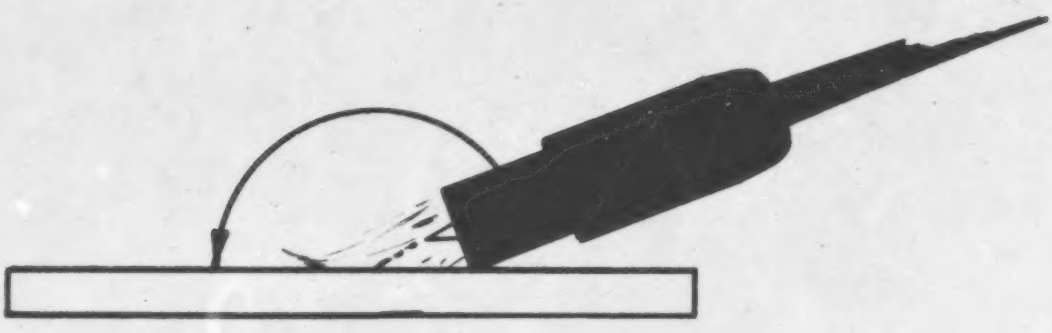
   a. in the inert gas envelope
   b. touching the electrode
   c. touching the puddle

8. What is necessary for uniform weld when adding filler metal.

   a. rhythm
   b. good eyes
   c. the torch

Starting the TIG arc is different from the stick electrode arc. You establish the arc instead of striking the arc. When you establish an arc, you do not touch the tungsten to the work.

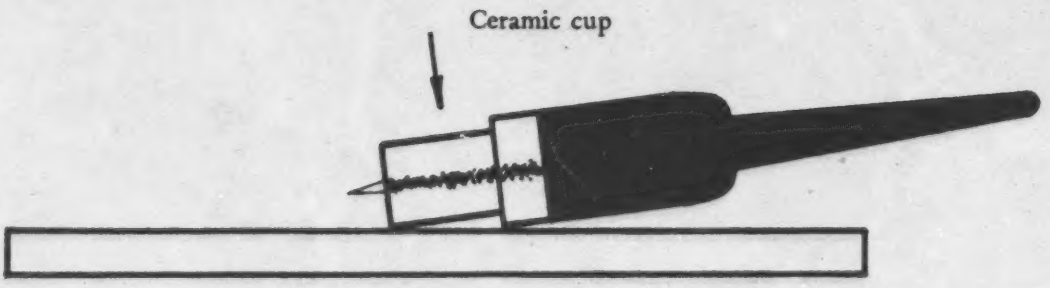
Establishing the Arc



The procedure for establishing the arc is:

1. Hold torch flat to work.
2. Push down foot control.
3. Slowly rotate torch until the arc starts.
4. Hold torch at proper angle and gap.
5. Adjust foot control until a puddle forms.
6. Begin welding.

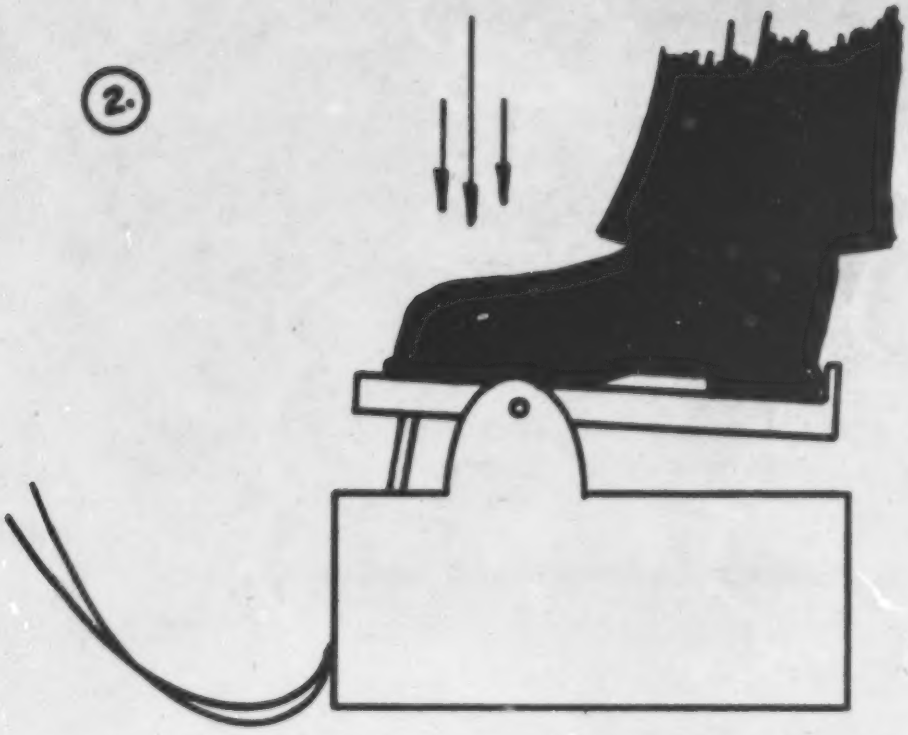
Take another look at the procedure for establishing a TIG arc. It is easy.



Hold torch flat to work

Hold torch flat to work. The only part that touches the work should be the ceramic cup. The tungsten should never touch the work when welding. Tungsten becomes contaminated when it touches the work. Tungsten is shiny until it touches metal; then it is dull.

Push down the foot control. The inert gas does not flow until the foot control is pushed down. Pushing down on the foot control also starts water flowing to the torch.



Push down foot control

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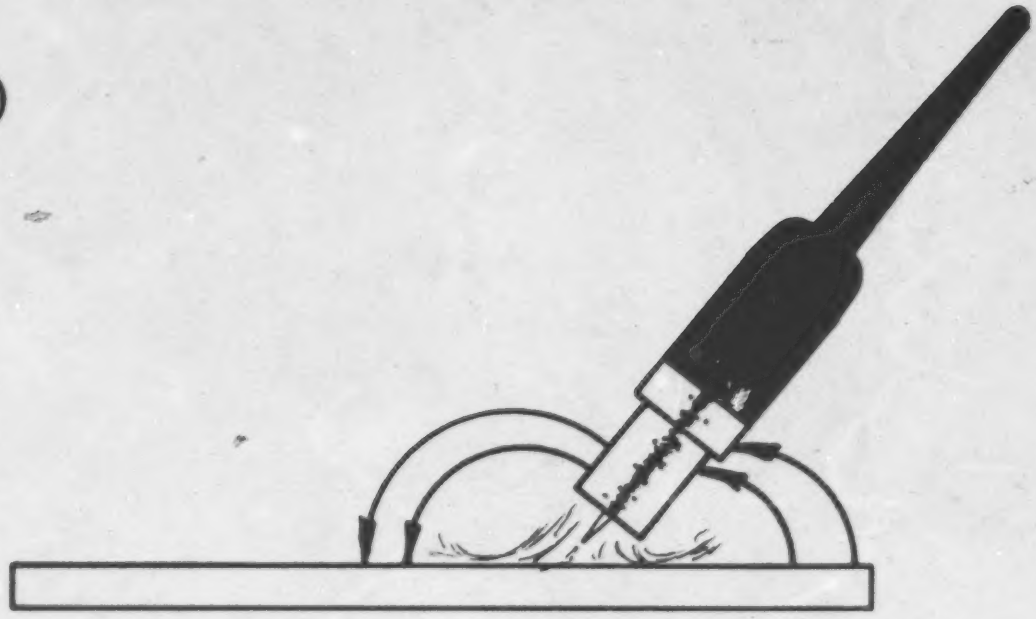
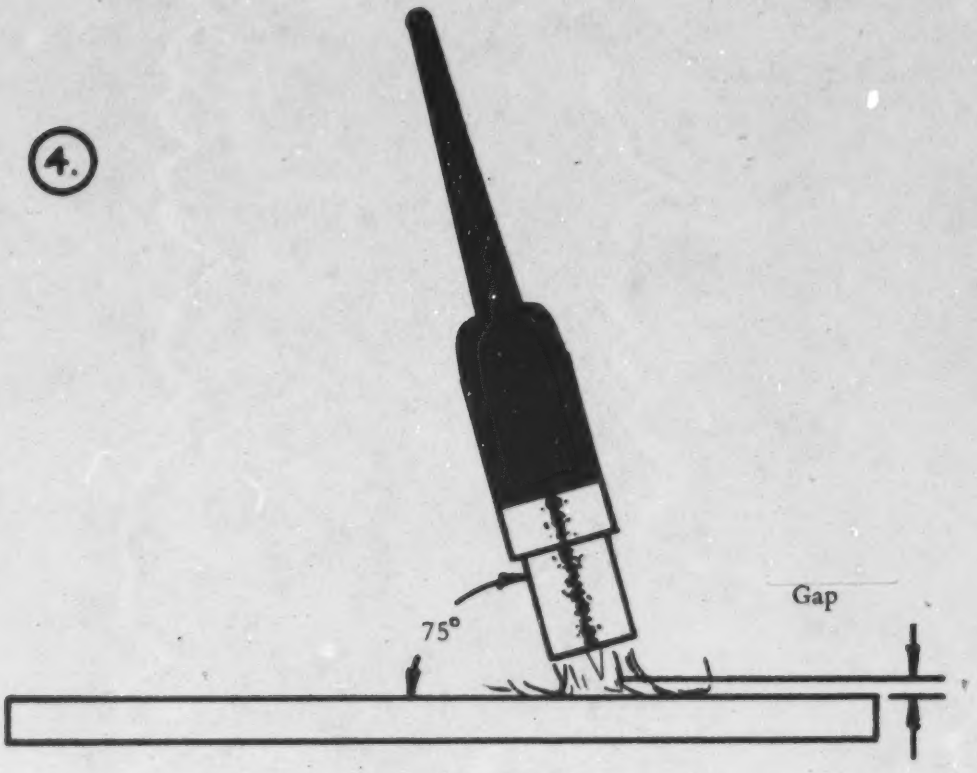
3.



Slowly rotate torch until arc starts

The electrons do not start to flow until the arc is established.

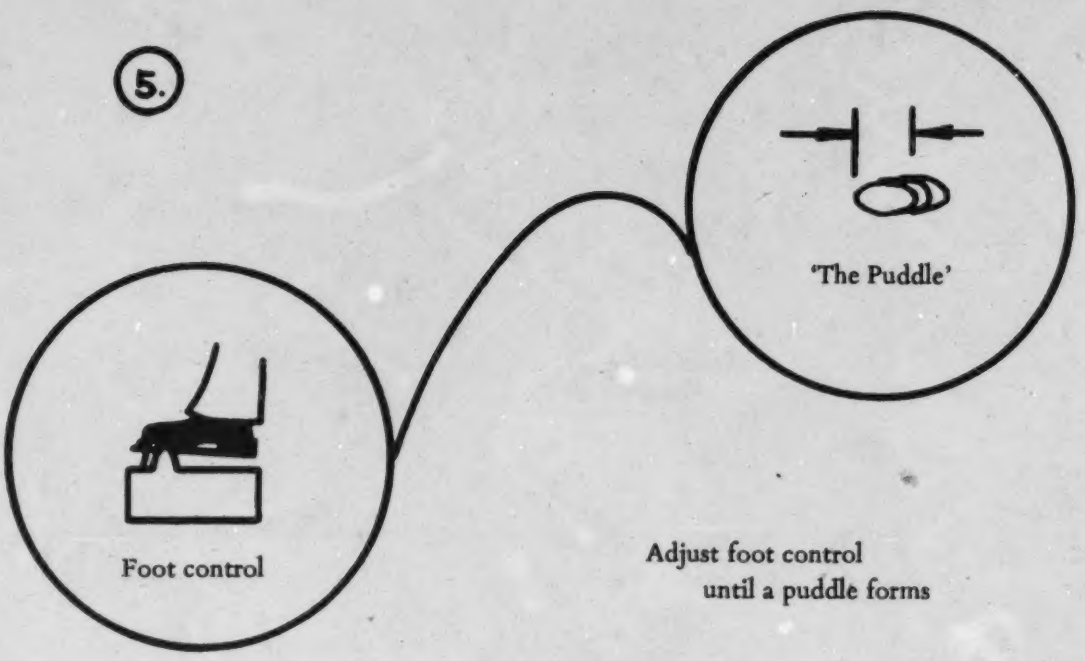
Lean torch in the direction that you are welding. Keep torch at a 75° angle.



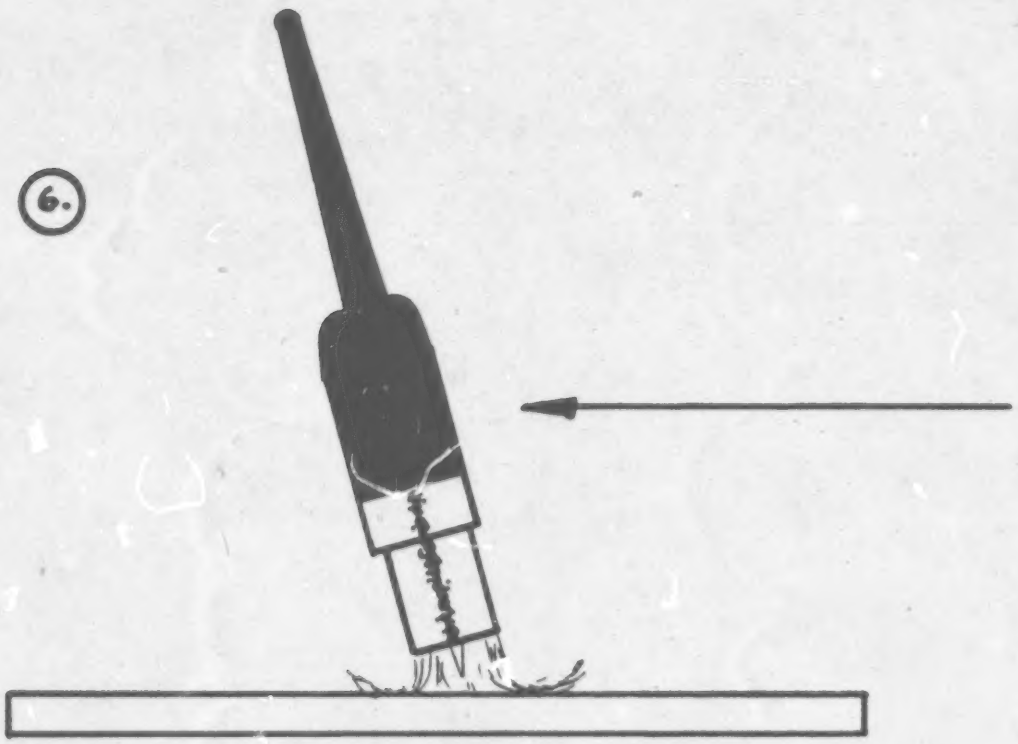
Hold torch at proper angle and gap

The gap should be equal to the diameter of the tungsten.

5.



Adjust foot control
until a puddle forms



Now, begin welding

You have begun welding. A good weld is a uniform weld.

REVIEW

Keeping tungsten electrodes clean is a special problem. Tungsten becomes contaminated when it touches metal during welding. Do not weld with a contaminated tungsten electrode. It does not make a good weld.

How do you know when a tungsten electrode is contaminated? Contaminated tungsten is dull. Tungsten should have a shiny finish.

What can you do with a contaminated tungsten electrode? Use a grinding wheel to make a new point on thoriated tungsten electrodes. You need a ball-shaped end with pure tungsten. Break the electrode off above the contaminated area with pure tungsten. Then, make a ball on the end of the electrode. First, turn the polarity switch to D.C.R.P. Now, establish an arc until the end becomes ball-shaped.

For electrodes that are not badly contaminated, establish an arc on a piece of copper. Often, the metal particles on the electrode will pass to the copper. Then, the tungsten is clean.

Remember, the steps for establishing an arc are:

1. Hold torch to work.
2. Push down foot control.
3. Slowly rotate torch until arc starts.
4. Hold torch at proper angle and gap.
5. Adjust foot control until a puddle forms.
6. Begin welding.

QUESTIONS

1. Can the electrode touch the work when establishing the arc?
   a. yes
   b. no
   c. sometimes

2. What touches the work in step one of the procedure?
   a. ceramic cup
   b. tungsten
   c. foot control

3. What is done to start the arc after the foot control is pushed down?
   a. power is turned on
   b. torch is slowly rotated
   c. work is rotated

4. How much of an angle is the torch held at, in the direction being welded?
   a. approximately 15°
   b. approximately 90°
   c. approximately 75°

5. What is adjusted until a puddle forms?
    a. ceramic cup
    b. tungsten arc
    c. foot control

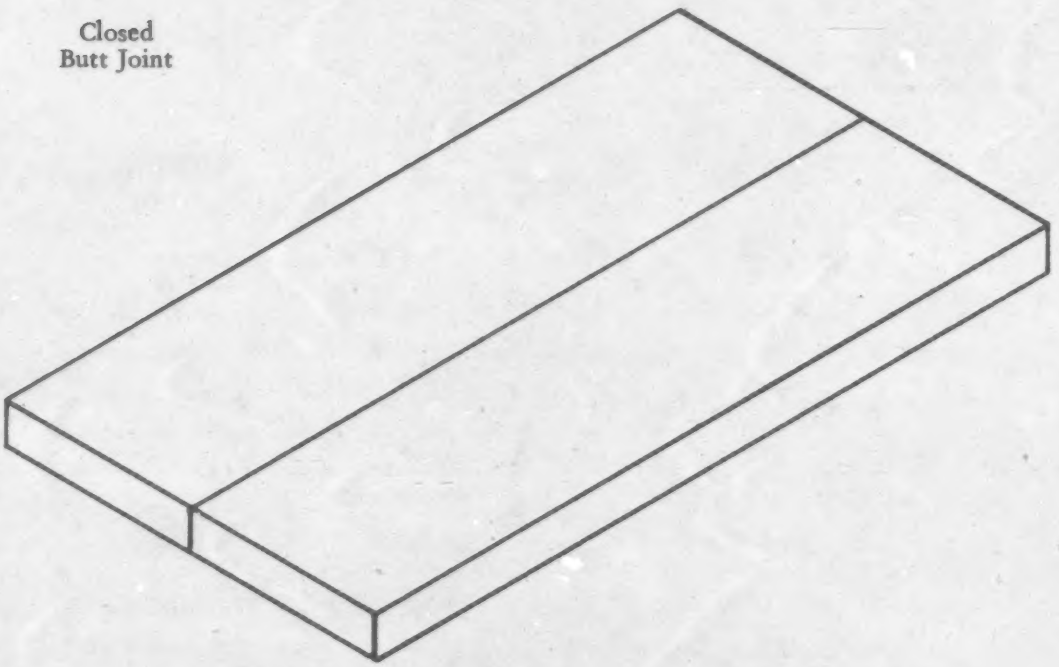
6. What determines the length of the arc?
    a. work
    b. gap
    c. stick-out

7. When does the inert gas and water to the torch begin to flow?
    a. after pushing down on the foot control
    b. after checking the gap
    c. after starting the machine

8. What happens when the electrode touches the work?
    a. becomes contaminated
    b. arc starts
    c. water starts flowing

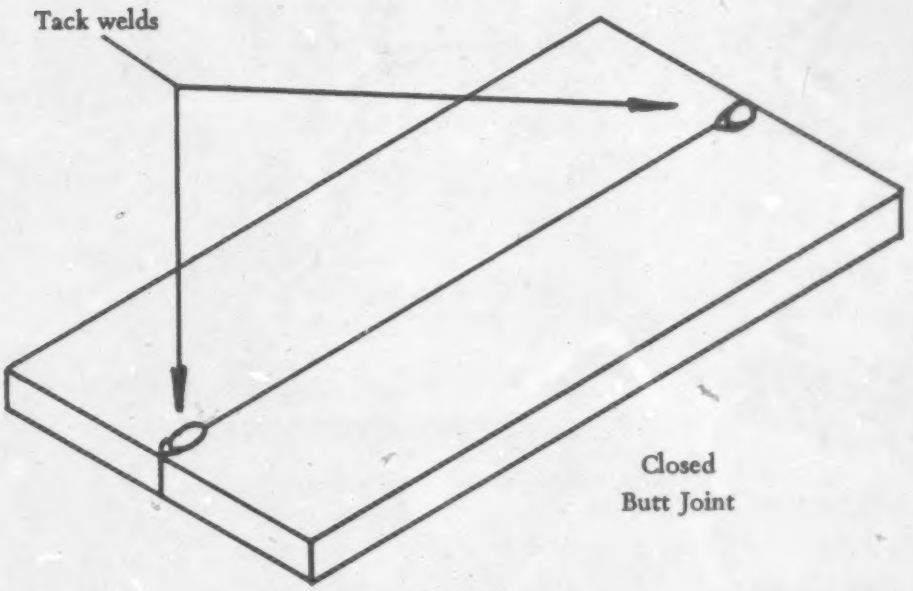
The butt weld is the most common type of weld. It has two pieces of metal placed edge to edge. You will see the closed butt joint and the chamfered butt joint in this lesson.

Closed
Butt Joint



This is a closed butt joint. The metal from the two pieces touch.

Tack welds are made at each end of a joint. The tack welds keep the pieces of metal from separating during welding. Long joints should have a tack weld at least every 6 inches.

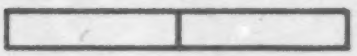


Closed
Butt Joint

It is easy to make a tack weld. Puddle the metal on both pieces at the joint. Then, move the torch in a small circle. The circular motion will join the metal puddles.

A closed butt joint is used for thin metal. You can get 100% penetration of thin metals with the correct current setting.

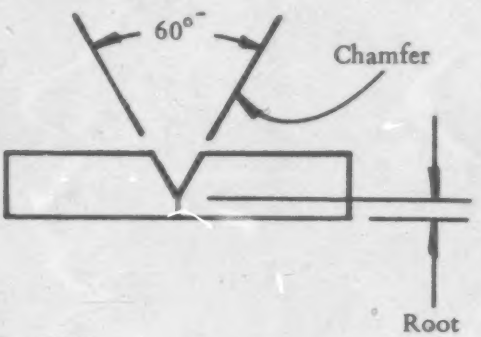
For thin metal



CLOSED
BUTT JOINT

A chamfered joint forms a VEE. Chamfered joints are used when the metal is 3/8" or more thick. This joint is called the single-vee butt.

For metal 3/8" and above



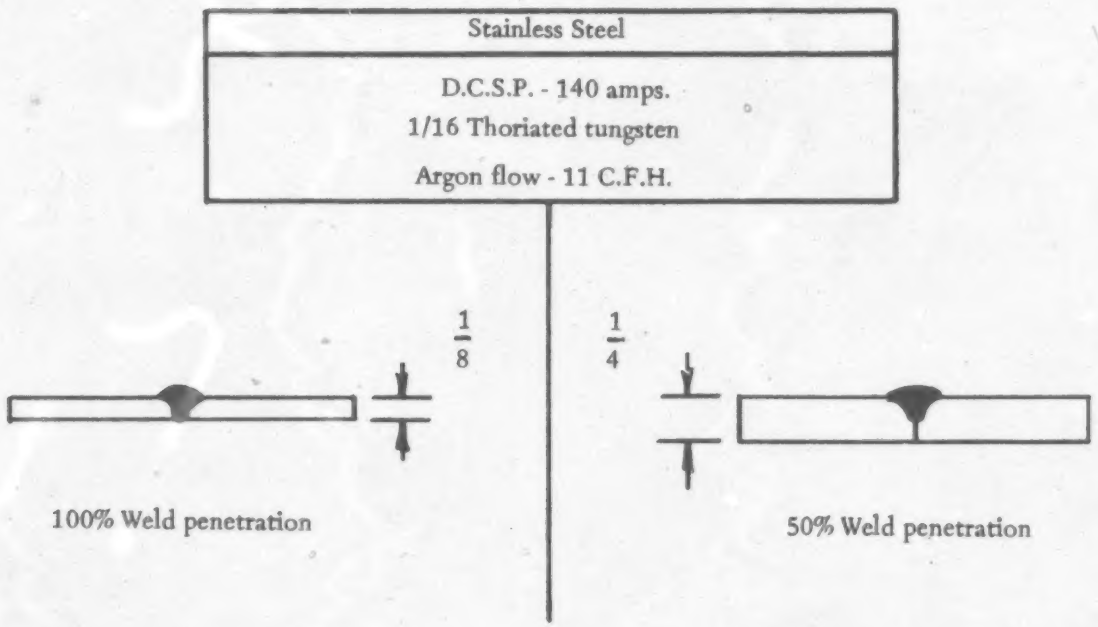
SINGLE – VEE
BUTT JOINT

Penetration is 100% wl.en the weld passes completely through the metal. 100% penetration is needed for maximum joint strength. 100% penetration is not needed for all welds. The designer decides on the amount of penetration. The welder makes the weld to the designers specification.

100% Weld penetration

Pentration is controlled by the amount of electrical current. Too much current can burn holes through the metal. These welds have 100% penetration. The welds pass completely through the metal.

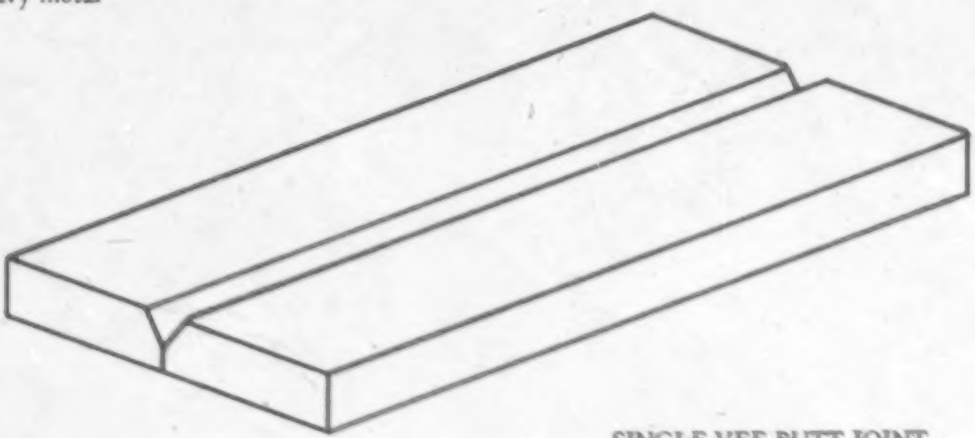
Look at the two butt joints. One is 1/8" thick; the other joint is 1/4" thick. The electrode diameter and current were the same for both joints. The thin metal had 100% penetration; the thicker metal had 50% penetration.



Check the penetration needed for each job. Use the correct current setting and electrode size for the necessary penetration.

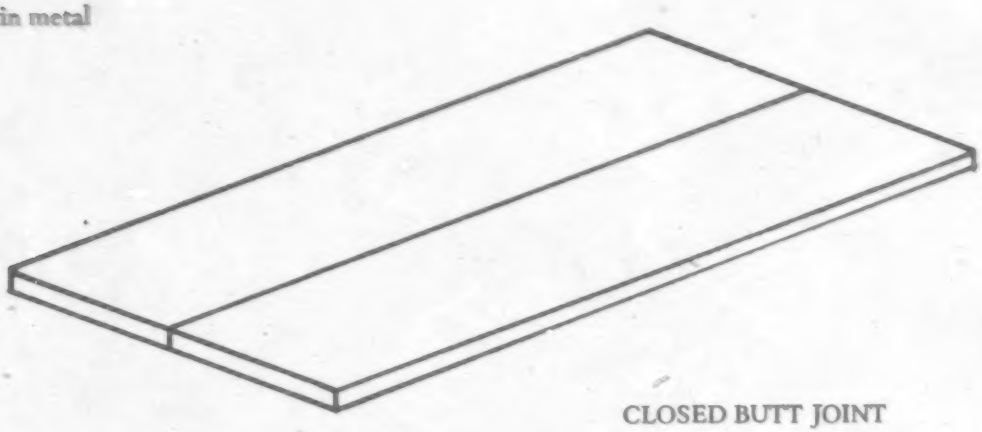
Check the thickness of the metal before welding. The single-vee butt joint is used for heavy metal. The closed butt joint makes a good weld with thin metal.

For heavy metal



SINGLE-VEE BUTT JOINT

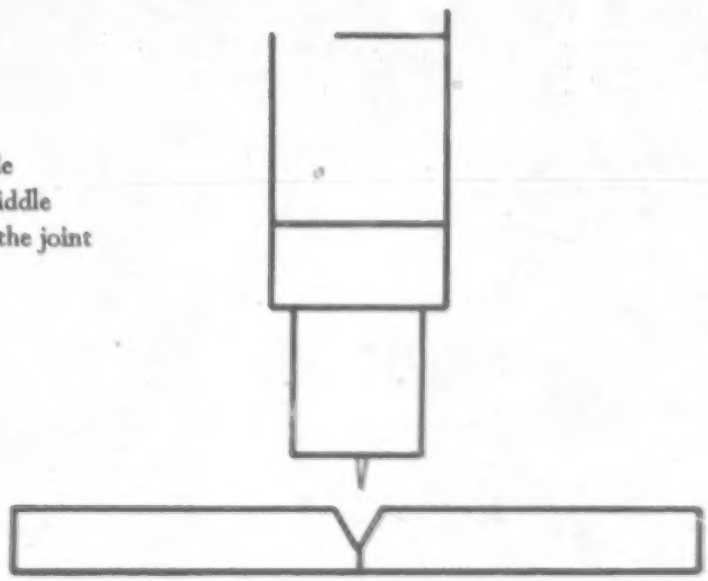
For thin metal



CLOSED BUTT JOINT

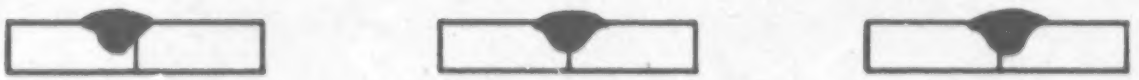
Aim the tungsten electrode at the middle of the joint. Keep the weld in the middle of the joint for the strongest weld.

Aim electrode
at the middle
of the joint



Results: Strong joint

Look at the three butt welds. They look the same from a top view. Only one weld was made in the middle of the joint. The other two welds will fatigue when we test them with a mechanical tester.



Which two joints will fatigue?

Take another look at the welds after testing them with a mechanical tester.

Fatigued | Strong Weld | Fatigued

The weld in the middle of the joint is strong. The welds at the side of the joint were weak. They fatigued when they were tested.

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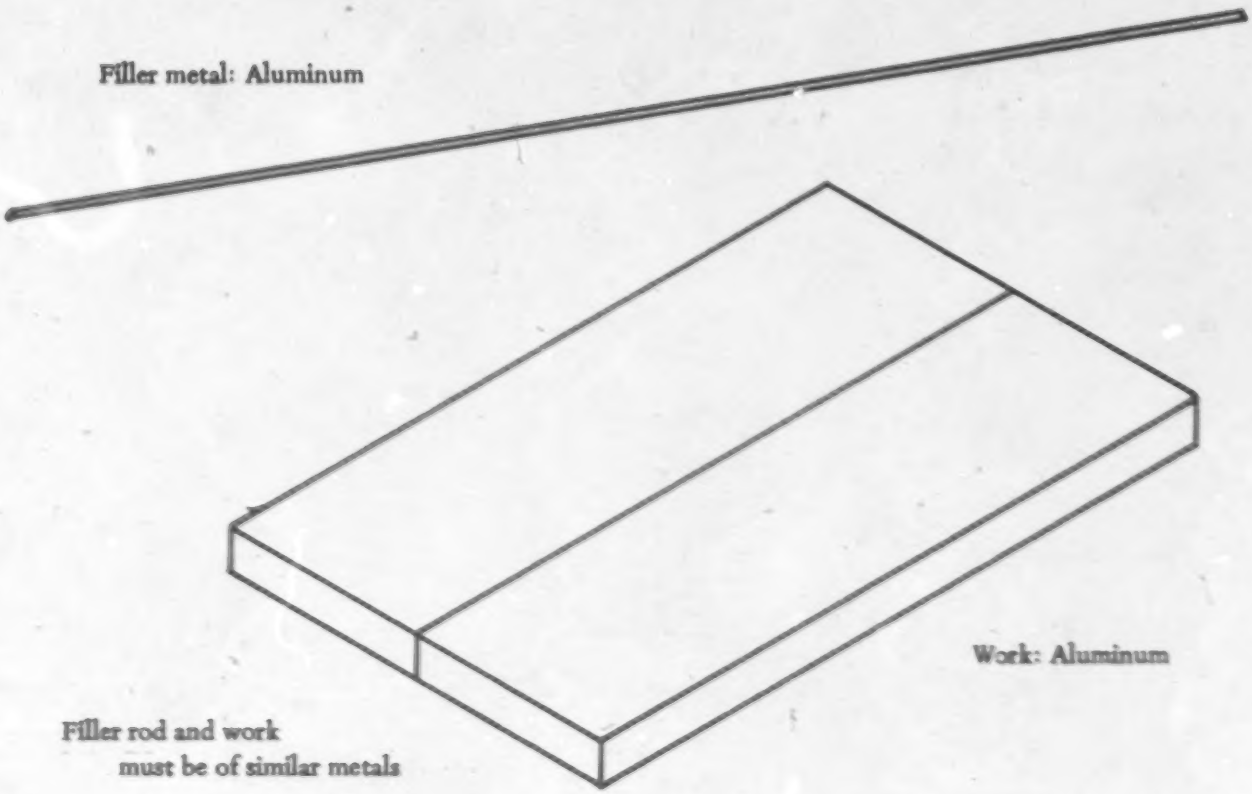
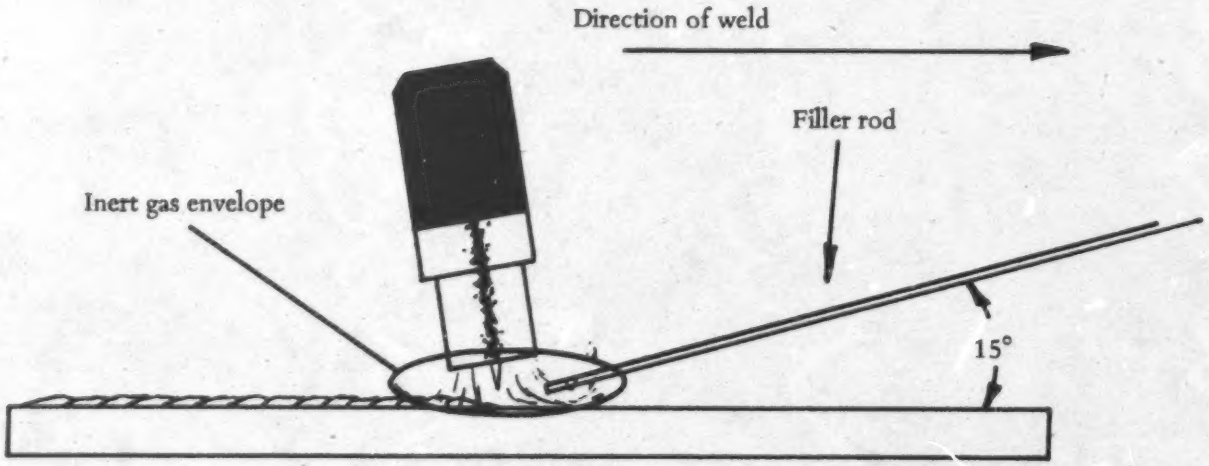
Add filler metal to the weld when it is needed. The filler metal should be like the metal being welded. If aluminum is being welded, an aluminum filler rod is used. If stainless steel is being welded, stainless steel filler metal is used.



Filler rod and work
must be of similar metals

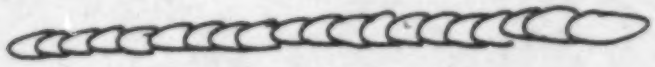
The filler rod should be held at a 15° angle to the work. Keep the rod in the inert gas envelope. Do not touch the tungsten electrode with the filler rod. Add the filler metal to the puddle using a rhythm.



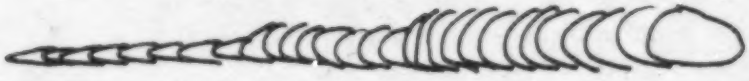
Position of filler rod to work

Review the steps of adding filler rod in Lesson 7 for more information.

Keep the weld looking the same from the beginning to the end. A good weld is made by controlling the puddle. This weld was made with an even welding speed.



The speed of this weld was changed from too fast to too slow.



It takes practice to make good welds.

REVIEW

- The butt weld is the most common type of weld.
- The closed butt joint is used for metal 1/8" or less thick.
- The chamfered butt joint is used for metal at least 3/8" thick.
- 100% penetration makes the strongest weld.
- Tack weld every 6 inches and at the ends before welding along a joint.
- Weld in the center of the joint for a strong weld.
- Add filler metal when needed. Use the same kind of filler metal as the metal being welded. Use aluminum filler metal when welding aluminum, etc.
- Keep the filler rod in the gas envelope during welding.
- Keep an even weld from beginning to end.

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QUESTIONS

1. Which one of the following is not a butt joint?
   a. closed
   b. 'T'
   c. single 'V'

2. The joint should be _____ to prevent separation when making a weld.
   a. butted together
   b. designed properly
   c. tack welded

3. For metals thicker than 3/8", what butt joint design is best?
   a. single-vee butt
   b. closed butt
   c. open butt

4. Maximum joint strength happens when the weld penetration is _____ through the metal.
   a. 100%
   b. 50%
   c. 10%

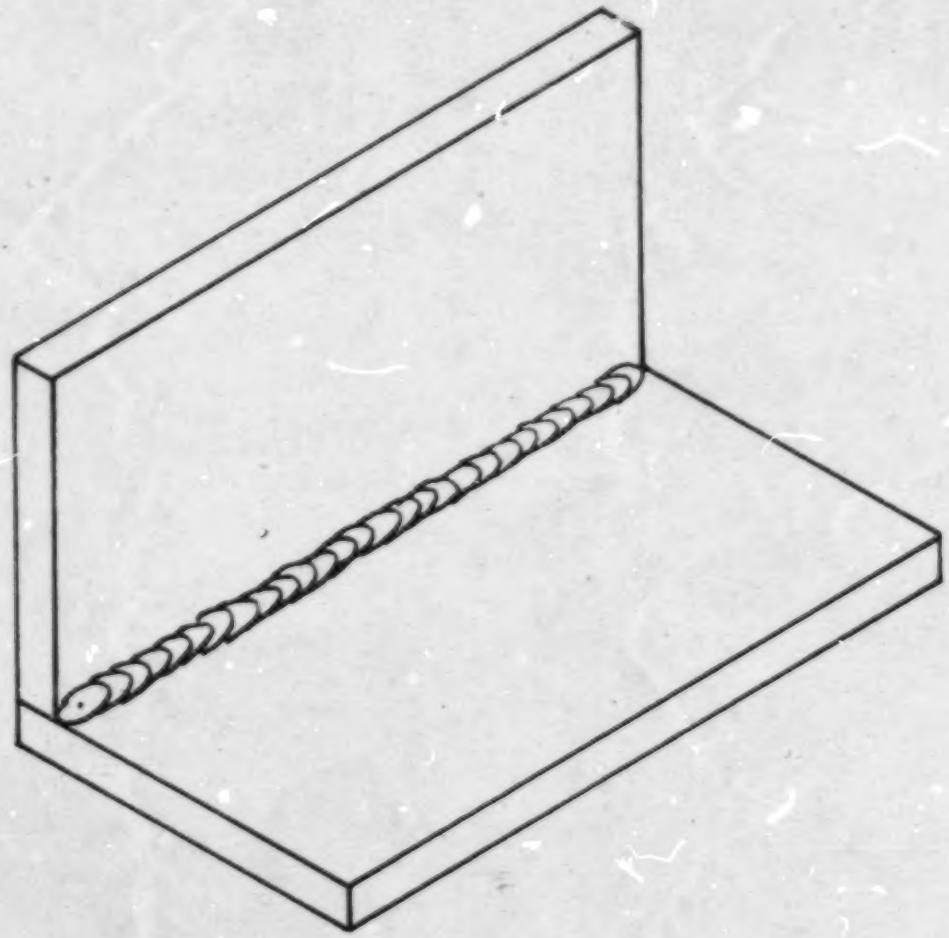
5. Where should the electrode be aimed when making the weld?
   a. r ht side of the joint
   b. middle of the joint
   c. left side of the joint

6. What will happen if the weld is not placed properly.
   a. it will fatigue
   b. it will be strong
   c. nothing

7. What is added to the weld?
   a. tungsten
   b. zirconium
   c. filler metal

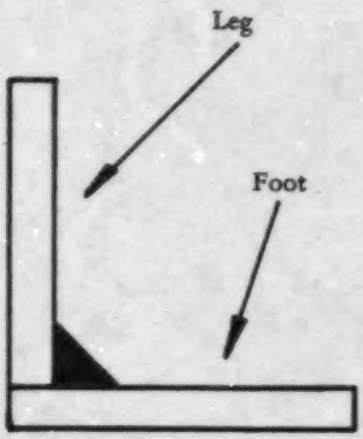
8. Draw a picture of a weld made at an even speed.

A fillet weld joins two pieces of metal for a corner joint. The fillet weld should fill the corner. This lesson shows how to make a horizontal fillet weld.

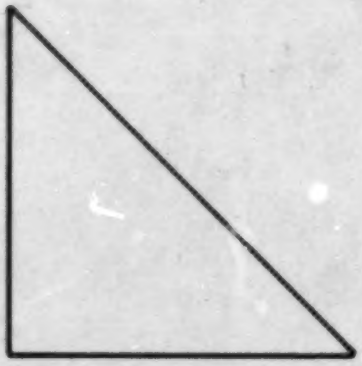


FILLET WELD

The two pieces of metal for the horizontal fillet weld are called the leg and the foot. The leg is the vertical or upright piece. The flat piece of metal is the foot.



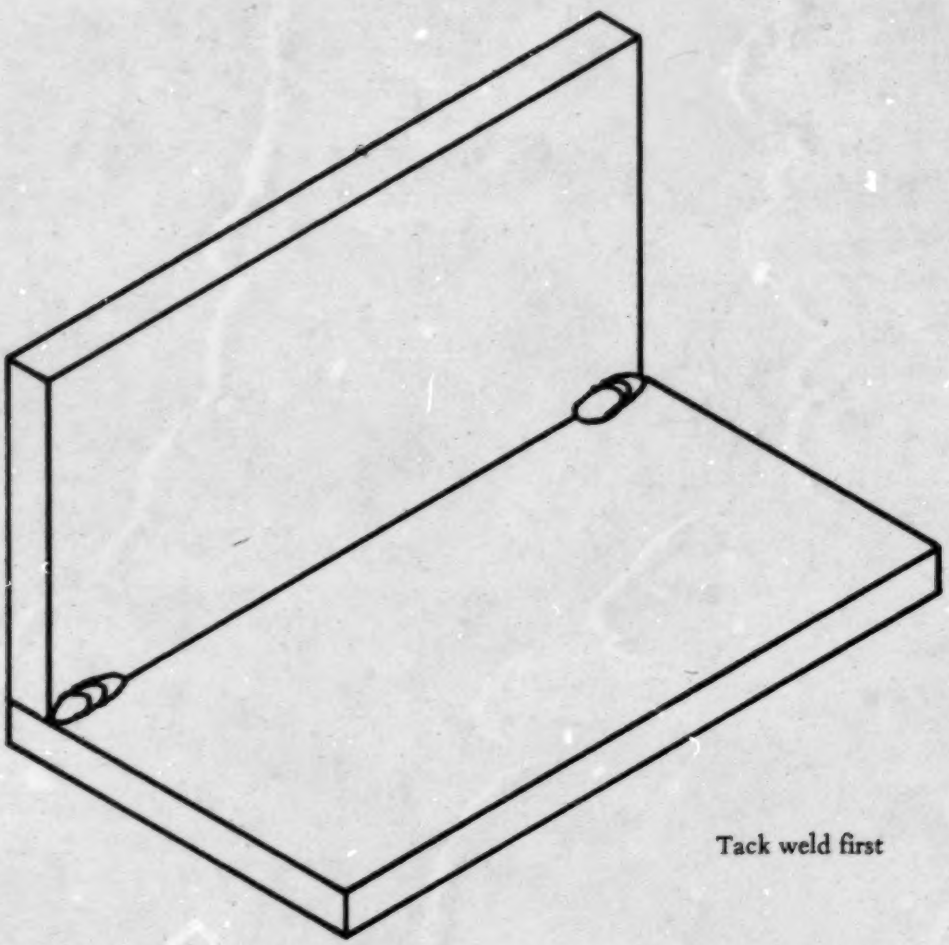
Good fillet weld



45° Triangle

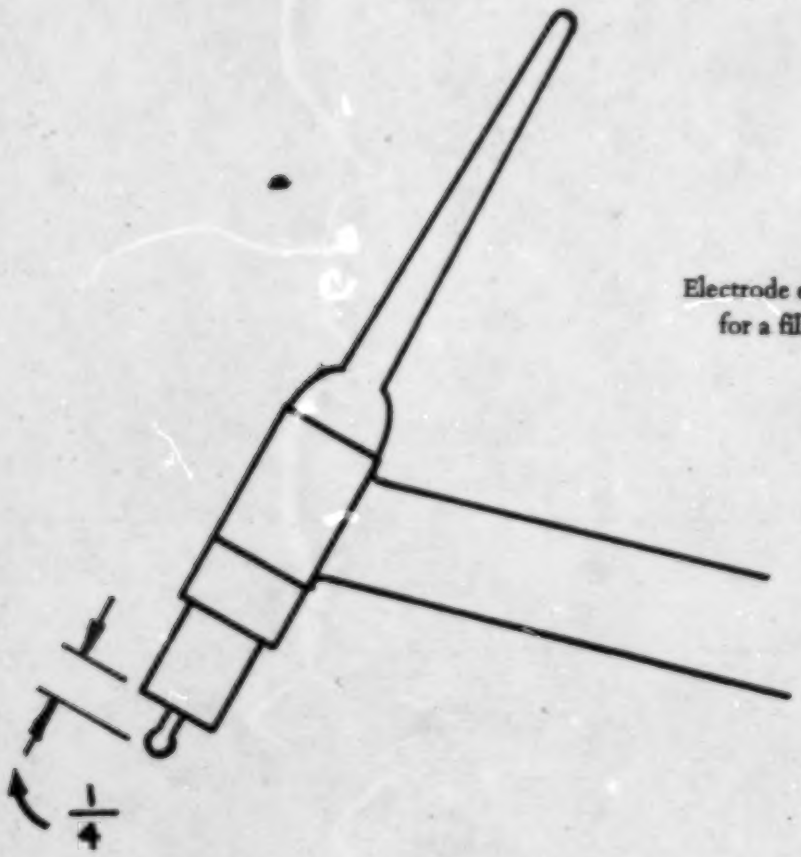
Look at the fillet weld above. A good fillet weld should look like a 45° triangle from the side view.

Tack weld the two pieces of metal before making a fillet weld. The tack welds hold the pieces so they can't move when you make the fillet weld.



Tack weld first

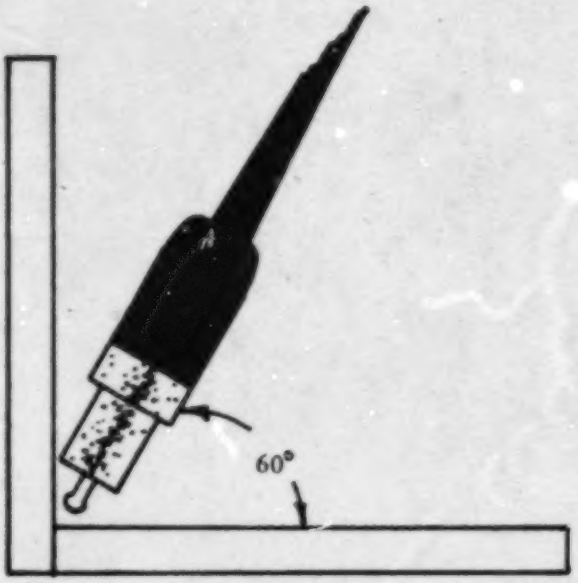
The tungsten electrode can be extended up to 1/4" for the fillet weld. The 1/4" is measured from the ceramic cup to the end of the electrode.



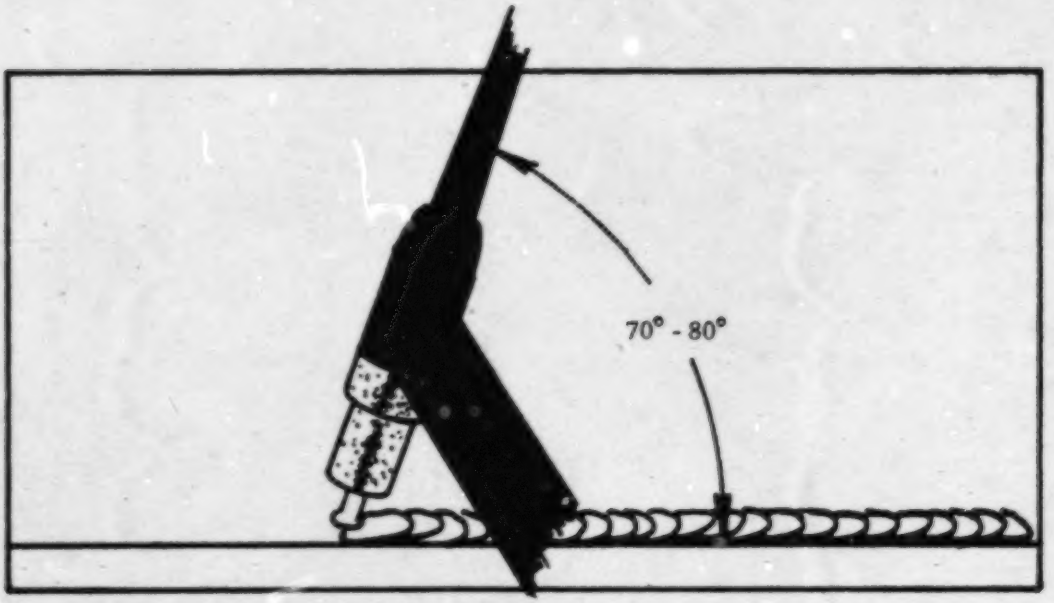
Electrode extension
for a fillet weld

Remember, the size of the ceramic cup depends on the electrode diameter and the joint design.

The torch should have a 60° angle to the work from the side view. It should also be slanted at a 70° - 80° angle away from the direction of the weld from the front view.

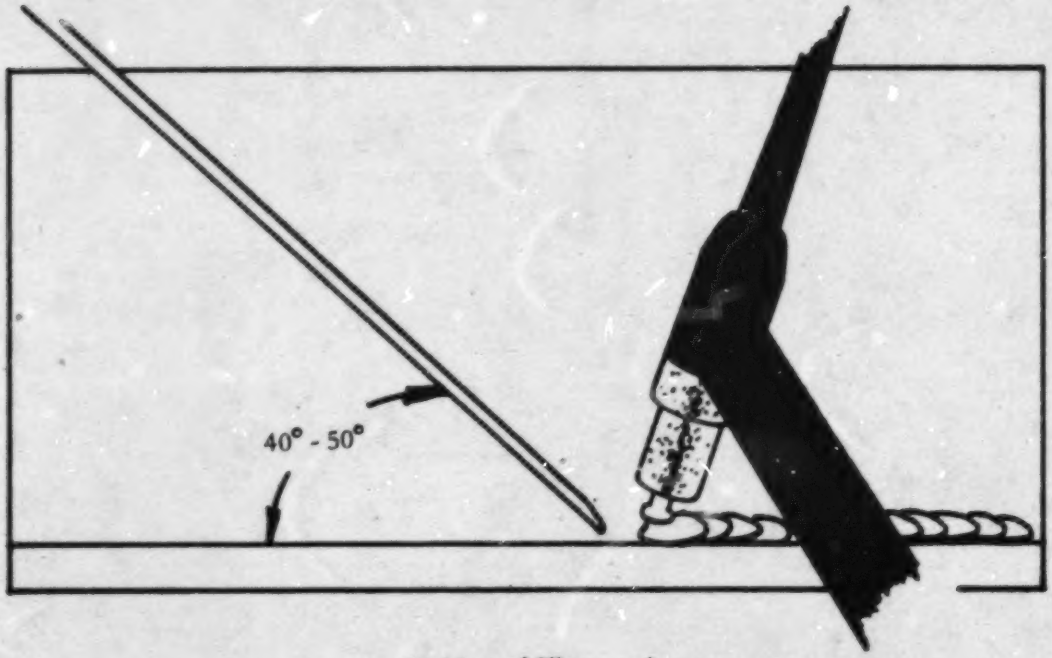


Side view



Front view

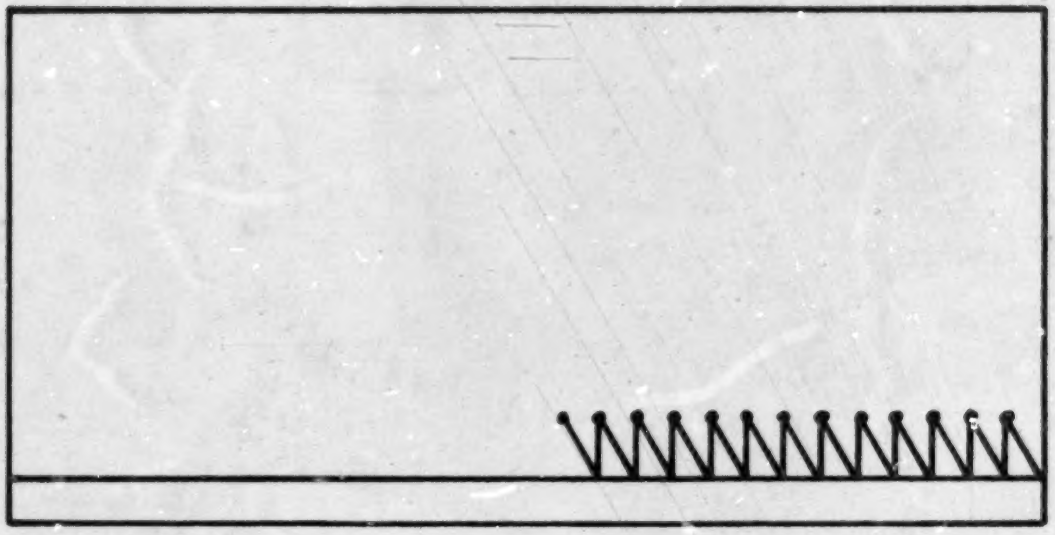
Hold the filler rod at a 40° to 50° angle to the work. Add the filler metal to the puddle with an even rhythm. You must also keep the filler metal in the inert gas envelope.



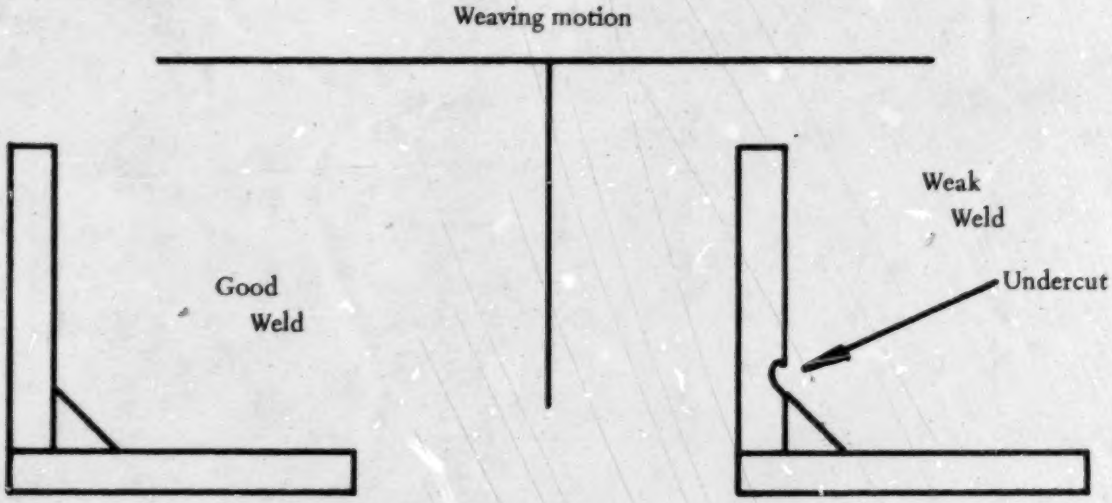
Position of filler metal

The key to a good weld is the puddle. The puddle size must be even for the entire weld. The puddle is controlled with the remote foot control. Less power is needed after the weld is started. The remote foot control is used to control the amount of power. Practice until you can control the size of the puddle.

Move the torch in a weaving motion when making a horizontal fillet weld. Pause at the top of the weave for better puddle control. The weaving motion prevents undercut.



• Denotes pause



Look at the welds above. The weld on the left was made with a weaving motion. The weld on the right was made without a weaving motion. The weaving motion helps to make a strong weld.

REVIEW

- A fillet weld joins two pieces of metal for a corner joint.
- The vertical piece of metal for the fillet weld is the leg; the flat piece of metal is the foot.
- Tack weld to keep the metal pieces from moving when you are making the fillet weld.
- The tungsten electrode can be extended up to 1/4" for the fillet weld.
- The torch should have a 60° angle from the side view. The torch should also be slanted 70° to 80° away from the direction of the weld from the front view.
- Hold the filler rod at a 40° to 50° angle to the work.
- Puddle size should be even for the entire weld.

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QUESTIONS

1. A fillet weld should form a _____ angle between the two pieces of metal.
   a. 75°
   b. 35°
   c. 45°

2. The vertical member in a horizontal fillet weld is called the _____.
   a. leg
   b. foot
   c. toe

3. The tungsten electrode extension for a fillet weld can be as much as _____ inch.
   a. 1/2
   b. 1/4
   c. 1/8

4. The torch should form about a _____ angle with the foot of the joint.
   a. 70° - 80°
   b. 60°
   c. 50°

5. The filler metal should be held at a _____ angle to the work.
   a. 40°- 50°
   b. 50°- 60°
   c. 30°- 40°

6. When should a pause be made when using a weaving motion?

   a. bottom of motion

   b. a pause is not necessary

   c. top of motion

7. A weaving motion is used to prevent _____.

   a. undercut

   b. a good weld

   c. weld porosity

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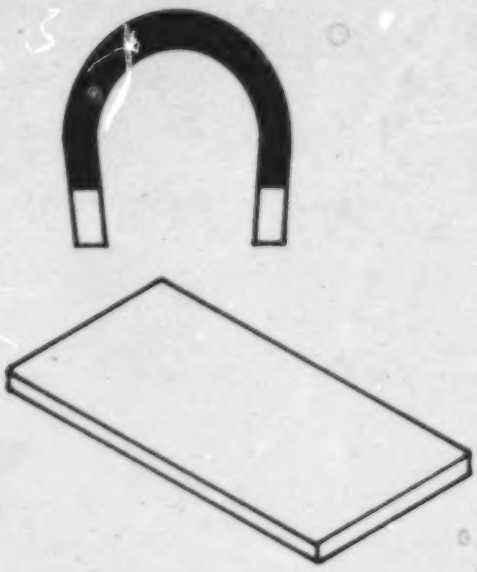
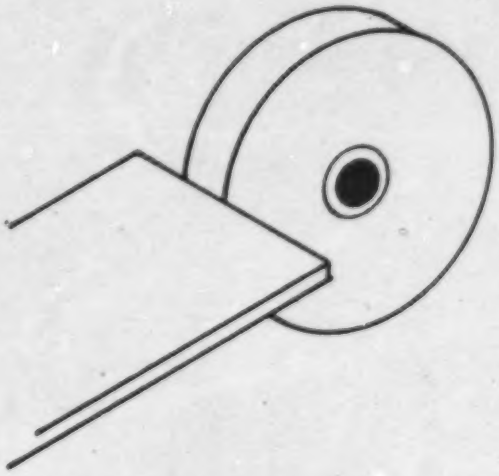
A quick test for aluminum is the spark test. Aluminum is non-magnetic and does not have a spark pattern. Other ways of identifying aluminum from steel are: (1) it is lighter and (2) it does not rust. Aluminum is a light gray metal.

Non-magnetic



No spark pattern



Tests for Aluminum

Clean aluminum before welding. Oxides on the surface of the aluminum must be removed. These oxides can weaken the weld. Aluminum can be cleaned with a stainless steel brush, a file, etc.

There are many aluminum alloys. The filler metal used for these aluminum alloys may be different. The most common filler metal is pure aluminum. Sometimes, a silicon-treated aluminum rod is used. The type of filler rod depends on the alloy being welded. If the aluminum alloy is not known, use a pure aluminum filler rod.

Remember, a green end, pure tungsten electrode will give best results when welding aluminum.

This chart is used when TIG welding aluminum. The figures are needed for computing the fine current adjustments. The fine current adjustment on the machine shown in Lesson 3 is based on a percentage of the range selected. Look at this chart when following the procedure for setting up the machine to weld aluminum.

Data for Welding Aluminum				
Thickness in Inches	Tungsten Electrode Diameter	Filler Rod Diameter	Flow Rate of Argon in Cu. Ft.-Hr.	No. of H.F.R.C. Amperes
1/16	1/16	1/16	15-20	60-80
1/8	3/32	3/32 or 1/8	17-25	125-145
3/16	1/8	1/8	21-30	190-220
1/4	3/16	1/8 to 3/16	25-35	260-300

The lower numbers for argon are for welding in the flat position; the higher numbers are for welding out of position. Reduce the current.

Procedure for Welding
Aluminum

1. Set polarity switch to A.C.

2. Set high frequency control to continuous.

3. When using remote foot control, set contactor control switch and amperage control switch to remote position.

4. Set current range selector to proper range. (Determine range from data sheet.)

5. Set fine current control to limits of tungsten electrode. (Compute from data sheet.)

6. Turn cylinder of argon on; then adjust flow. (Determine flow from data sheet.)

7. Turn on-off switch to on position.

8. Turn water tank motor switch to on position. This is important to prevent burning out of torch.

9. Adjust tungsten electrode for proper extension (1/8" for flat position, 1/4" for horizontal fillet weld).

10. Attach work to ground clamp or grounded bench.

You are now ready to weld. Many hours of practice are needed to learn the skills of a good welder.

Preparing Tungsten Electrode

A ball-shaped pure tungsten electrode should be used to weld aluminum. The ball shape can be made by:

1. Turning the polarity switch to D.C. reverse polarity.

2. Establishing an arc on a copper block.

3. Hold the arc and increase the power (with foot control) until a ball forms on the end of the electrode.

4. The ball should not measure more than 1½ times the diameter of the electrode.

5. After the ball is made, change the polarity switch to A.C. power.

REVIEW

- Aluminum does not have a spark pattern when tested on the grinder.
- Clean oxides from aluminum before welding.
- When welding aluminum alloys, use a pure aluminum filler rod if the aluminum alloy is not known.
- A green end, pure tungsten electrode will give best results when welding aluminum.
- A ball-shaped pure tungsten electrode is used to weld aluminum.

QUESTIONS

1. Is aluminum magnetic?
   a. yes
   b. no

2. Does aluminum have a spark pattern?
   a. no
   b. yes

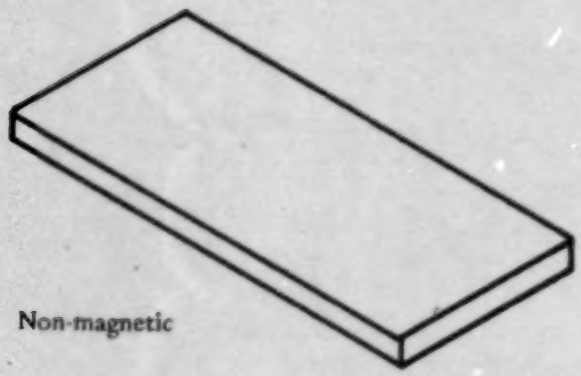
3. How much power is needed to weld 1/16" thick aluminum.
   a. 15-20 amps.
   b. 25-35 amps.
   c. 60-80 amps.

4. Where should the high frequency control be set?
   a. off position
   b. start only position
   c. continuous position

5. How much is the tungsten electrode extended for welding in the flat position?
   a. 1/16"
   b. 1/8"
   c. 1/4"

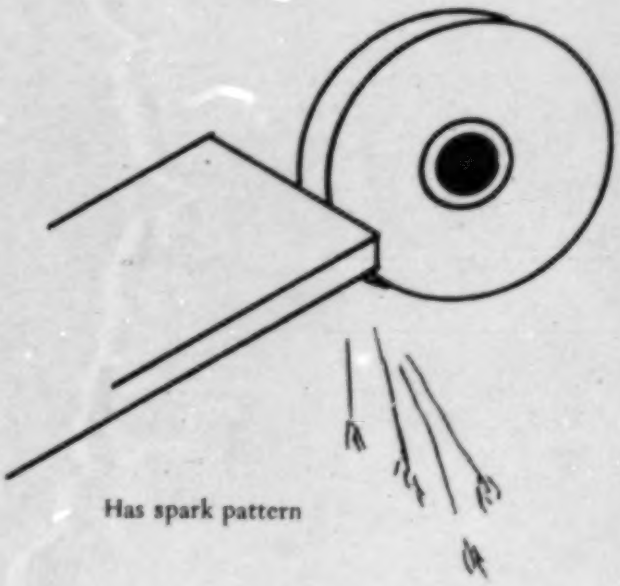
6. Before welding, what should be done to the aluminum?
   a. nothing
   b. cleaned
   c. welded

Stainless steel is a non-magnetic metal that has a spark pattern. It can be a bright or dull silver color. Most stainless steels do not rust.



Non-magnetic

TESTS FOR
STAINLESS STEEL



Has spark pattern

Stainless steel should be cleaned before welding. Cleaning removes most of the surface oxides. These oxides weaken the weld if they are not removed. Stainless steel can be cleaned with a wire brush or other mechanical cleaning methods.

Stainless steel does not always need a filler rod. If the joint is designed properly, the filler metal is not needed. When a filler rod is needed, choose a filler rod that is closest to the alloy being welded.

Before welding, the tungsten electrode is ground to a point for best results. It can be pointed on a grinding wheel or an aluminum oxide belt. The point should be slightly blunted. The process of pointing the tungsten allows the electrons to flow to a point; it makes a smooth arc.

Use a 2% thoriated tungsten electrode for stainless steel.

This chart is used when TIG welding stainless steel. The figures in the chart are needed to figure the fine current adjustment. Other TIG welding machines may have a different means of adjusting the current than the machine shown in Lesson 3. Use this chart for setting up the machine to weld stainless steel.

Data For Welding Stainless Steel				
Thickness in Inches	Tungsten Electrode Diameter	Filler Rod Diameter	Flow Rate of Argon in Cu. Ft. per Hr.	Number of D.C.S.P. Amperes
1/16	1/16	1/16	11-15	80-100
3/32	1/16	3/32	11-15	100-120
1/8	1/16	3/32	15-18	120-140
3/16	3/32	1/8	15-18	200-250

Use the lower argon numbers for flat welds and the higher numbers for out-of-position welds. Current values are for flat welding. Reduce the current by 10-20% for vertical and overhead welds.

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Procedure for Welding
Stainless Steel

1. Set polarity switch to D.C.S.P.

2. Set high frequency to start only.

3. When using remote foot control, set contactor control switch and amperage control switch to remote position.

4. Set current range selector to proper range. (Be careful when selecting range because A.C. current values are different from D.C. current values in the same position.)

5. Set fine current control to limits of tungsten electrode diameter. (Compute from data sheet.)

6. Turn cylinder of argon on; then adjust flow. (Do this when machine is turned on. Determine the amount of gas needed from the data sheet.)

7. Turn on-off switch to on position.

8. Turn water tank motor switch to on position. Important: this prevents burnout of the torch.

9. Adjust tungsten electrode extension. (1/8" maximum for flat position; 1/4" maximum for horizontal fillet weld.)

10. Attach work to ground clamp or grounded surface.

11. Shut off machine by turning on-off switch off; turn water tank motor switch off and close the tank of argon.

After the first 10 steps have been followed, welding can begin. Remember, good welds are the result of practice.

REVIEW

- Stainless steel is a non-magnetic metal that has a spark pattern.
- Clean oxides from stainless steel before welding.
- D.C.S.P. current is used to weld stainless steel.
- A 2% thoriated tungsten electrode is used to weld stainless steel.
- A pointed electrode makes the smoothest arc with stainless steel.

QUESTIONS

1. Stainless steel has a spark pattern.
   a. true
   b. false

2. What kind of current is used to weld stainless steel?
   a. A.C.H.F.
   b. D.C.S.P.
   c. D.C.R.P.

3. What kind of tungsten electrode should be used to weld stainless steel?
   a. pure
   b. none
   c. 2% thoriated